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A study of the correlation potential of the optimum moisture content, maximum dry density, and consolidated drained shear strength of plastic fine-grained soils with index properties

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A STUDY OF THE CORRELATION POTENTIAL OF THE OPTIMUM MOISTURE CONTENT, MAXIMUM DRY DENSITY, AND CONSOLIDATED DRAINED SHEAR STRENGTH OF PLASTIC FINE-GRAINED SOILS WITH INDEX PROPERTIES

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ABSTRACT

The correlation potential of the compaction properties and the consolidated drained shear strength parameters of plastic fine-grained soils with index properties was investigated in this study. The interrelationships of these properties were derived through graphical and multilinear regression analysis.

The compaction properties, optimum moisture content, and maximum dry density were found to be related to many of the index properties. The most important relationships were with the plasticity indices and the percentage of particles smaller than two microns; the highest degree of simple correlation was achieved with the liquid limit.

The consolidated drained shear parameters, cohesion, and the angle of internal friction were correlated with many of the index properties; however, the magnitude of the computed correlation coefficients were not indicative of a high degree of correlation. The correlation of the shear parameters with the plasticity index was the most significant.

Many useful equations and graphical procedures for rapidly predicting the compaction and shear parameters from index properties have been developed. The accuracy of these equations and graphical procedures has been evaluated herein and found to be sufficiently accurate for most prediction situations.

Through varied data considerations, it was determined that the best approach to accurate correlation would be to restrict the analyses to soils of similar origin or to those of a limited geographic area, in lieu of focusing upon soils of varied origin as a unit. The investigator is hopeful that this fact and other facts brought out herein will prove useful to those attempting similar studies in the future.

Preface

Soil has been used as an embankment and foundation material since early times. The procedures followed in identifying and evaluating these materials both during design and construction have changed radically from the rather crude empirical procedures of early times to the more refined procedures employed by the engineer today. Today's soil and construction engineers have at their disposal a variety of laboratory classification tests which they can use to determine the index properties of the various soils which may be encountered. Numerous laboratory tests for the evaluation of the engineering properties of soils are also available.

Past studies have revealed a close interrelationship between many of the engineering and index properties of soils. Establishing these relationships through analysis of laboratory test data will not only increase our basic understanding of soils, but will offer several other distinct advantages to those working in soil mechanics and other allied fields. The primary purpose of this dissertation is to investigate the relationships between the optimum moisture content, maximum dry density, consolidated drained shear strength, and index properties, and to develop through mathematical and graphical analyses equations and graphical procedures which can be used to accurately predict these engineering properties.

Important contributions to the content of this dissertation were made by so many friends and colleagues that it would be impossible to mention them all here. I would, however, like to acknowledge the assistance of and to express my sincere appreciation to my advisor, Dr. T. Fry. I would also like to acknowledge with thanks the cooperation of Dr. Joseph W. Senne and Mr. Bruce H. Moore; my gratitude to Miss Neale Zinser for typing this dissertation. And finally, I owe my greatest debt to my wife and two sons for their forbearance.

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I. INTRODUCTION

A. Purpose of Investigation.

Engineers in design and construction, as well as laboratory technicians, have long recognized the potential of accurately correlating the engineering properties of soild with their index properties. They have also recognized the advantages afforded by the development of accurate prediction procedures which could be derived from these correlations. The purpose of this dissertation is twofold: (1) to investigate the interrelationships and correlation potential of three engineering properties, optimum moisture content, maximum dry density, and the consolidated drained shear strength, with their index properties; (2) to develop equations and graphical procedures which can be used to predict these engineering properties. The investigator's choice to investigate these three properties was based upon the consideration of those properties from which the most benefit could be derived if accurately correlated, upon his needs as a civil engineer involved in embankment design, and the availability of laboratory test data. The development of accurate prediction procedures will provide the following distinct advantages to the engineer in the office, field, and laboratory.

1. These procedures will provide a means of rapidly approximating these properties when time is of the essence.

2. Considerable cost reduction in laboratory test programs can be derived if sufficiently accurate prediction procedures can be developed. The option exists of using these procedures in lieu of performing the costly and time consuming laboratory test. It is not intended to develop prediction procedures which will eliminate completely the need

for these tests; however, through the use of such procedures, the number of tests required for design and construction control purposes can be greatly reduced. A reduction in required testing will undoubtedly result in economy both during design and construction.

3. A means of rapidly checking the validity of laboratory test results will be provided. Office and field engineers often find themselves at a disadvantage when trying to establish the validity of test results, which for some reason may appear to be in error. These engineers may be far displaced from the laboratory where the testing was performed, and may therefore have no means of rapidly verifying the accuracy of the results. However, if good correlation can be established for the soild in a given geographical location, it will be a simple matter to detect erroneous test results and thereby form the basis for the engineer's request for check test.

4. Accurate prediction procedures will be very useful to the laboratory technician who must perform these tests. He often has to estimate the range of moisture contents in compacting specimens for the standard Proctor test. The moisture range selected is often in error, and may necessitate the preparation and compaction of additional specimens at either higher or lower moisture contents in order to fully develop the Proctor curve. The availability of accurate prediction procedures will preclude such additional testing, and will ultimately result in savings in both time and cost.

5. These procedures will provide a means of detecting soils differing substantially from those previously encountered. Often during construction, materials are encountered which have entirely different properties from those which were evaluated during design. The

importance of detecting and evaluating these soils prior to incorporating them in the structure cannot be overemphasized. Such materials when placed inadvertently in the past have resulted in problematic conditions both during and after construction. If correlation procedures can be derived prior to construction, the field engineer and inspector will have an excellent tool which will enable them to rapidly detect these troublemakers.

B. Scope.

This investigation will be limited to the fine-grain soils of the primary soil divisions, including residual, loessial, glacial, waterlaid soils of the coastal plains, soils of the filled valleys, and recent alluvium. The investigator has elected to concentrate his efforts on the plastic fine-grain soils of these divisions because they are more frequently encountered during the construction of embankments than the nonplastic fine-grain soils. For the above reason and for the lack of sufficient test data on nonplastic fine-grain soils, no consideration will be given to the nonplastic variety in this study.

Initially, an attempt will be made to establish correlation, prediction equations, and graphical procedures, using test data on samples representing all major soil divisions to ascertain the prediction accuracy which can be achieved when soils of different origin are considered together. Then attention will be focused upon the soils of the individual groups, i.e., residual, glacial, loessial, etc., to establish if a much higher degree of correlation can be achieved by limiting the analysis to soils of similar origin. Then, finally, the soils of one geographic area will be analyzed to determine the correlation potential of the soils within a very small geographic or project area.

C. Methods of Analysis.

Plotting procedures, correlation methods, and multiple linear regression analyses will be used in this study to examine the interrelationships which exist between the engineering properties and soil index properties. Arithmetic and logarithm plots will be used in conjunction with correlation methods to determine how strongly these properties are related. Multiple linear regression analyses will then be used to develop useful prediction equations. Multiple linear regression analysis is a mathematical procedure for obtaining an equation for estimating a dependent variable by means of several independent variables. This analysis is based upon the assumption that an approximately linear relationship exists between the dependent and independent variables. The analysis will provide the linear equation that best fits the data. Several combinations of independent variables (index properties) will be studied for each dependent variable (engineering properties) under consideration. Graphical prediction procedures will then be developed from the results of the regression analysis. The tools of error analysis will be used to evaluate the accuracy of both the prediction equations and graphical procedures.

D. Test Data.

The laboratory test data used in this study were obtained from two U. S. Army Corps of Engineer installations, the Waterways Experiment Station located in Vicksburg, Mississippi, and the South Atlantic Division located in Atlanta, Georgia. These data were carefully extracted from the soils portion of design memoranda for past and present Corps of Engineer projects, which were on file at these installations. These memoranda dealt with the embankment design for large reservoir projects located within the continental United States. Data were collected on 317 soil samples from 20 states. Sampling locations are shown on figure 1. The data included the mechanical analysis, specific gravity, Atterberg limits, standard Proctor compaction, and direct shear test results. The data have been tabulated and are presented in table V. All testing was performed at either the Waterways Experiment Station or at Corps of Engineer Division laboratories located throughout the country. The procedures followed in performing these tests were standard, and were in accordance with procedures outlined in the laboratory testing manual of the Corps of Engineers, which is entitled Laboratory Soils Testing and is designated Engineering Manual 1110-2-1906.

The investigator is cognizant of the innate error which may be present in laboratory results collected from several different sources. A recent report(7)* published by the U. S. Army Corps of Engineer Waterways Experiment Station, entitled "Preliminary Analysis of Results of Division Laboratory Tests on Standard Soils Samples", explored the variation of test results obtained from different Division laboratories. Standard samples were prepared at the Waterways Experiment Station and then shipped to all Corps of Engineer Division laboratories. These laboratories were instructed to perform the Atterberg limits, grain size analysis, standard effort compaction, and the triaxial compression R test, utilizing standard Corps of Engineer procedures. The results of these tests indicated a wide variation in the measured properties, especially for values of the optimum moisture content, maximum dry

*Numbers in parentheses refer to listings in Bibliography.

density, and shear strength. The results of such studies can be used to develop correction factors, based upon deviations from test averages, for data used in correlation studies, especially those considering test results from several sources. It was the initial intention of this investigation to employ correction factors to the raw data collected based upon the results of the above discussed report; however, information regarding the laboratories performing these tests has been temporarily withheld by the Office of the Chief of Engineers in Washington. For this reason, no attempt can be made in this investigation to apply correction factors to the raw data. This does appear to be an area of consideration that should be explored in future correlation studies.

II. REVIEW OF THE LITERATURE

A. Early Attempts of Correlation.

Engineers and laboratory technicians have made numerous attempts to correlate the engineering properties of soils with their index properties since the early 1900's. Early attempts at correlation consisted of rather crude field methods developed for construction control. For example, R. R. Proctor[2] in 1933 developed a field method of correlating the optimum moisture content and maximum dry density with a crude measure of plasticity by means of a plasticity needle penetration resistance test. This method was based upon the variation of soil plasticity with moisture content. The penetration resistance was defined as the pressure required to force a rod with a slightly enlarged bearing surface, to penetrate the soil at a rate of about one-half-inch per second. These readings were made for each compacted specimen used in developing the Proctor curve. From these data, convenient plots such as shown on figure 2 could be made. These plots were then utilized in conjunction with plasticity needle readings made in the newly placed fill to relate field moisture and density to the Proctor optimums. This method of relating the optimum moisture and density to what is essentially a measure of plasticity was used quite extensively during the early 30's for field control.

B. Ohio State Engineering Experiment Station Report[3].

In July 1938, the Engineering Experiment Station of Ohio State University published a report which established the general relationships between the optimum moisture and maximum density, and their relationships to plasticity characteristics. Plots similar to those developed in this study, which included data on Ohio soil samples numbering over one thousand, are shown on figure 3. These plots revealed very strikingly the increase in optimum moisture content with increase in the plasticity characteristics and a decrease in the maximum dry density with increase in the plasticity characteristics. The relationship between maximum density and optimum moisture was also brought out in this study. As can be seen from the examination of graph C of figure 3, there is a very definite increase in the maximum density with decrease in the optimum moisture content.

C. Vanderbilt University Study[4].

In a report published by Vanderbilt University in July 1948 entitled "Proper Compaction Eliminates Curing Period in Constructing Fills," two equations were developed which can be used to closely approximate the optimum moisture content and maximum dry density:

$$\text{Maximum dry density in pounds} = \frac{D}{1 + \frac{D-C}{62.5G_s}}$$

$$\text{Optimum moisture contents (in \%)} = SL(B/A)$$

where:

$D = \frac{CA}{B}$

A = % passing No. 4 sieve

B = % passing No. 40 sieve

G_s = Specific gravity

SL = Shrinkage limit

C = 62.5xR (Shrinkage ratio), pcf

These equations are based upon the assumption that the maximum dry density and optimum moisture content are equivalent to the density that can be achieved by compacting a specimen at the shrinkage limit, where the available water just fills the voids of the soil mass. To verify the accuracy of these equations, standard density tests were performed on 10 soil samples with widely varying index properties. The greatest difference between the predicted and test maximum was about 5%; the optimum moisture contents predicted were slightly higher, from about 1 to 5 points.

The report recommended a reduction of three moisture points in the predicted value of the optimum moisture content, in order to more closely approximate the optimum as defined by the standard 25-blow Proctor test.

D. Davidson and Gardiner[5].

Davidson and Gardiner, recognizing the advantages of the two equations developed in the Vanderbilt study, decided to more thoroughly evaluate the accuracy of the predicted results. They felt that the amount of supporting data did not warrant unqualified use of these equations, especially since only 10 samples were used in the report to establish their validity.

Two hundred and ten soil samples from widespread geographical localities in the United States were selected to verify the accuracy of the optimum moisture and maximum dry density preduction equations. Davidson and Gardiner found that the calculated and laboratory values did not reflect the high degree of correlation as was reported by Vanderbilt. As a whole, the results were so inconsistent and often so much in error that the validity of the formulas was questioned. Davidson and Gardiner found that the magnitude of the error both in the case of the optimum moisture and the maximum dry density was related to the plasticity index. Plots of error versus the plasticity index were made for both properties. These plots, shown on figure 4, revealed a near linear relationship between the error and the plasticity index. Davidson and Gardiner decided to correct the original Vanderbilt equations in accordance with their findings. The modified equations resulting from the application of correction factors were written:

$$\text{Maximum dry density} = \frac{6250\ K_1}{S(\frac{B}{A} - 1) + \frac{100}{R}}$$

$$\text{Optimum moisture} = S(B/A) + K_2$$

where:

$$K_1 = \frac{312-2X}{300}$$

$$K_2 = X/3-4$$

$$X = \text{Plasticity Index}$$

These results are considered sufficiently accurate to warrant their use for prediction purposes where a high degree of accuracy is not necessary. Davidson and Gardiner point out that the greatest limitation of these modified formulas is that they cannot be used with accuracy for soils having a high organic content. Organic matter is highly absorptive, which makes it extremely difficult to make precise determination of the shrinkage and plasticity indexes involved. Use of these equations was not recommended where rigid control or specification work is under consideration.

E. Turnbull (6).

At the Second International Conference on Soil Mechanics and Foundation Engineering, Turnbull, of Austrailia, presented a paper in which he correlated the optimum moisture content with a gradation characteristic which he designated as the classification area. The classification area was defined as the area above the graph of the grain size distribution curve when plotted on a special chart devised by Turnbull to facilitate area determinations. One hundred and eighty compaction tests on 101 soils were used to establish the relationship between the optimum moisture content and the classification area. Compaction was performed utilizing 25 and 40 blows per 2-inch layer of a 5.5-pound hammer freely falling a height of 18 inches. Two plots were made to show the relationship of the optimum moisture content to the classification area for the 25 and 40 blow efforts; these plots are presented on figure 5. This chart was found to fit the test data very closely; 72 percent of the predicted optimum moisture contents was within ±1.0 percentage point of the actual test result and 91 percent of the value falls within a range of ±1.5. It was concluded that grain size distribution alone could be used to effectively predict the optimum moisture content.

F. Kawano and Holmes[7].

Y. Kawano and W. E. Holmes reported the results of their attempt to correlate optimum moisture with the Atterberg limits of 30 soil samples from the Island of Oahu, Hawaii. These soils were taken from the surface horizons and subsoils at 15 sampling sites and represented 13 soil types. The procedures described by Lambe[8] were used for the standard Proctor compaction test and limit tests. Throughout these investigations, the plastic limit was found to approximate the Proctor optimum moisture by not more than a few moisture points. There were exceptions, however, which deviated considerably. For this reason, Kawano and Holmes decided to investigate the potential of correlating the optimum moisture content with limit data. Correlation coefficients were developed for the plastic limit, liquid limit, and plasticity index with optimum moisture. These coefficients were .854, .437, and .300, respectively. These values indicated that the correlation with the plastic limit to be highly significant and the correlation with the liquid limit to be only slightly significant. The correlation with the plasticity index was nonsignificant. Since the plastic limit was found to be most significant of the indexes considered, a regression analysis was made utilizing the plastic limit and optimum moisture data. The following equation resulted:

$$\text{Optimum moisture} = 11.2 + 0.672 \text{ plastic limit}$$

This equation was found to be very useful in predicting the optimum moisture for the soil types considered; however, since the regression analysis was based upon a very limited number of observations, this equation should be used with caution even for soils within the very small geographic area of Oahu.

G. Jumikis[9].

In 1958, A. R. Jumikis, professor of Civil Engineering at Rutger's University, published a paper entitled "Geology and Soils of the Newark (N. J.) Metropolitan Area". Professor Jumikis reported on the major soil types encountered and mapped in the glaciated Newark metropolitan area. Jumikis explored the relationships between optimum moisture content, maximum dry density, gradation characteristics, and plasticity. Jumikis concluded the following:

1. A very definite maximum dry density exists for each soil type encountered.

2. There is a general trend of increasing maximum dry density with increasing percentage fines.

3. Decreasing optimum moisture content occurs with increasing maximum dry density.

4. There is an increase in optimum moisture content with an increase in plasticity.

A graph was presented in this paper correlating the optimum moisture content (standard Proctor) with the liquid limit and plasticity index. This graph has been found to be very useful in predicting the optimum moisture content of the glacial soils found in the Neward area and other glacial soil area. This graph is shown on figure 6.

H. Bureau of Public Roads Studies[10].

The physical Research Division of the Bureau of Public Roads has conducted two major studies to correlate the results of laboratory compaction tests with the results of classification tests. The correlations established in these studies have been proven useful, and have found much application in the office, laboratory, and field. The first study, in 1958, consisted mainly of plotting maximum dry density and optimum moisture contents against the plastic and liquid limits to the arithmetic scale. This study was based upon test data of 972 soil samples from 31 states. The most fruitful result of this study was the development of a chart by Yemington[11], which is used quite extensively today for prediction purposes. This chart is shown on figure 7. The accuracy of this chart was verified by using it to estimate the optimum moisture contents for 510 additional soil samples from a number of states. The comparison of these results with the actual test data is presented on figure 8. This chart shows that 81 percent of the predicted values was within two moisture content percentage points of the actual laboratory optimum moisture content. The correlation was best for soils east of the Mississippi River and least for soils from non-soil areas west of the Mississippi River. The accuracy of the maximum dry density from the chart was investigated by making estimates of the density for 532 laboratory samples including the original 510 verification samples. Sixty-three percent was within 4 psf of the corresponding test results, which means that this chart is sufficiently accurate for most prediction situations.

In 1961, the Bureau made a second study[10] to improve the method of predicting optimum moisture content and maximum dry density using multiple linear regression analysis. This method was selected because it permitted the consideration of several variables to be used jointly for predicting the optimum moisture and maximum dry density. Six hundred soil samples were selected from the files of the Bureau based upon geographical and geologic origins of the samples. The independent variables used in the analysis included plastic limit, liquid limit, plasticity index, and several measures of gradation. The simple relationships were investigated by making arithmetic plots, which revealed good correlation potential of optimum moisture content with liquid limit and plastic limit, and good correlation of maximum dry density with optimum moisture content and plastic limit. Five regression analyses for the optimum moisture and four for the maximum dry density were made to determine prediction equations. Several types of operators were applied to the raw data including logarithmic transformation, and the addition of constants to some of the independent variables to achieve linearity. The most accurate equations developed for predicting the optimum moisture and the maximum dry density were as follow:

(1) $\text{Log O.MC} = 0.784 \log PL + 1.378 \log(FA^*+100) - 6.586$

(2) $\text{Log(Maximum Dry Density)} = 7.247 - 0.567 \log(PL+20) - 0.110 \log FA^*$

*FA was defined as one-sixth of the summation of the percentage of particles by weight finer than the following listed sizes in millimeters: 2.0 (No. 10), 0.42 (No. 40), 0.074 (No. 200), 0.020, 0.005, and 0.001. These relationships are also shown on graphs presented on figure 7. The standard errors of estimate for the optimum moisture and maximum dry density equations above were ±2.17 and ±4.32, respectively. (The standard error of estimate as defined by Hoel[12] is a measure of the scatter of points--test results--from the regression line represented by the prediction equation.) The normal distribution of error was found to hold so that it can be assumed that 67 percent of the predicted optimum moisture contents and maximum dry densities will be within one standard error, or ±2.17 percent moisture and ±4.32 pounds, respectively. Ninety-fice percent of the predicted values will be within two standard errors, or ±4.34 percent moisture and ±8.64 pounds. Comparison of the prediction results based upon Yemington's chart and the results utilizing the equation developed in the second study revealed that predictions based upon the plastic limit and fineness average were slightly better than those obtained from the chart. It was concluded that the formulas developed during the second study, incorporating the various factors for estimating compaction test results, were considerably more reliable for a wide variety of soils than any previously published.

I. Bjerrum and Simons[13].

At the American Society of Civil Engineering Research Conference on Shear Strength of Cohesion Soils, Bjerrum and Simons presented a paper entitled "Comparison of Shear Strength Characteristics of

Normally Consolidated Clays". In this paper, the authors presented the results of their attempt to correlate the consolidated drained angle of shearing resistance with the plasticity index. Bjerrum and Simons report that their experience indicates that the friction angle for any given clay varies with so many different factors that a close correlation with any one characteristic describing a clay cannot be expected. However, they were able to establish a rough correlation with the plasticity index by plotting friction values for the consolidated drained strength against the plasticity index and then deriving a mean curve. A plot similar to the Bjerrum and Simon's curve is presented on figure 9. It should be noticed that the displacement from the mean curve is appreciable, and therefore use of this curve to approximate the consolidated drained strength should be limited to only those situations where a high degree of accuracy is not required.

J. Corps of Engineers Studies[14].

In 1962, the U. S. Army Waterways Experiment Station published a technical report entitled "The Engineering Properties of Fine-Grained Mississippi Valley Alluvial Soils Meander Belt and Backswamp Deposits". Data used in this study were obtained from U. S. Army Engineer Districts, St. Louis, Memphis, Vicksburg, and New Orleans. This report established the relationships of pertinent engineering properties of two of the fine-grained alluvial deposits of the Mississippi Valley and correlation of these properties with simple index properties. It also established useful information regarding the relationships between the index properties themselves. The following conclusions were warranted as a result of this study:

1. The relationship between liquid limit and plasticity index was found to be fairly constant for the deposits studied.

2. Useful correlations were developed between the following:

   a. Plasticity and grain size characteristics.

   b. Specific gravity and plasticity index.

   c. Compression index and liquid limit.

   d. Compression index and natural water content.

   e. Compaction characteristics and plasticity index.

3. This report also attempted to correlate the unconsolidated undrained (Q) and consolidated drained (S) shear strengths with index properties; the following conclusions were drawn:

a. The results of the attempts to correlate the unconsolidated undrained shear strength with natural water content and plasticity characteristics by plotting procedure did not indicate any correlations or trends of practical value.

b. The consolidated drained shear strength as determined in the direct shear test was found to be related to the plasticity index. Values of both shear parameters, ϕ and c, were plotted against the plasticity index. Values of ϕ ranged generally between 30 and 17 degrees, and tended to decrease with increasing values of plasticity index. Values of the cohesion parameter, c, ranged generally between 0 and 0.1 ton per square foot, and tended to increase with increasing values of plasticity index. The relationship between c in tons per square foot and plasticity index was approximately linear, and is given by the following equation: $c = 0.0015\ PI$. Plots taken from this report showing the relationships between these shear parameters and plasticity are presented on figure 10. It should be noted that the accuracy of these charts has been verified for only a limited number of soils and therefore should be used with caution. The report strongly recommended that the established correlations be corroborated and refined by continuing application of data obtained in future soils investigations.

The studies reviewed above represent only a small percentage of the total number of studies which have been made to investigate the interrelationships between the engineering properties of soils and their index properties. However, the studies reviewed here are considered to reflect the most significant developments which have been made up to this time.

The importance of publishing the results of correlation studies cannot be overemphasized, for it is onlv through the channels of communication that we can hope to obtain a well-informed profession. Although much useful information has been developed relative to these relationships, there is still a need for additional research to supplement our present knowledge and to establish more precise methods of prediction.

III. DISCUSSION

A. General.

The discussion which follows covers in detail the graphical procedures, multilinear regression analysis, error analysis, and a complete evaluation of the results of this study. The discussion will be presented in three segments to facilitate review. First, the graphical procedures employed to investigate the simple relationships between the engineering properties and their index properties will be discussed. Secondly, the procedures employed in the regression analysis and the results of this analysis will be presented. The final segment will consist of a complete evaluation of the results based upon error analysis.

B. Graphical Analysis.

Initially, arithmetic graphs of the optimum moisture content, maximum dry density, and both shear parameters versus the index properties were made to investigate the simple relationships between these properties. Graphs of the compaction properties versus the liquid limit, plastic limit, plasticity index, percentage of fines (passing the #200 sieve), percentage of clay (less than .002mm), percentage of sand (percent passing #4 sieve minus percent passing on #200 sieve), and the activity coefficient (PI/% clay) were made. The consolidated drained shear parameters, ϕ and c, were plotted against the optimum moisture content, maximum dry density, liquid limit, plastic limit, plasticity index, average sample water content (direct shear test), and percentage of fines. A graph of ϕ versus c and optimum moisture versus the maximum dry density was also made to determine the relationship between the engineering properties themselves.

The first series of graphs was made utilizing all the test data in one graph without regard to soil origin, then the scope of consideration was narrowed to the data on soils of the individual soil groups, and finally to the data on soils of one small geographic area. The second scope of consideration, individual soil groups, was limited to the data on residual and glacial soils because of data limitation. Those arithmetic graphs which indicated a high degree of correlation were also plotted to the logarithmic scale. These logarithmic graphs were then compared with the arithmetic graphs to determine whether increased linearity could be achieved. A linear relationship was desired in lieu of a curvilinear relationship because of the investigator's choice of linear regression analysis as a means of developing the desired prediction equations. These arithmetic and logarithmic graphs are presented to reflect the strong mathematical relationships between the independent variables (index properties) and the dependent variable (engineering properties), others to reflect the insignificance of the relationship. Note, many graphs which were deemed insignificant were omitted from this presentation.

1. Compaction Properties.

a. Optimum Moisture Content. The graphs which were developed using all the test data without regard to soil origin indicated the optimum moisture to be strongly related to the liquid limit, plasticity index, and the plastic limit, and slightly related to the activity coefficient, percentage fines, and percentage clay. The optimum moisture content versus liquid limit relationship was found to be the strongest of those index properties considered. However, the most direct relationship was obtained from the graph of optimum moisture content versus maximum dry density, figure 22. Graphs based upon data on soils from residual soils areas also indicated a strong relationship between the optimum moisture content and plasticity characteristics. The linearity of these graphs was somewhat greater than the graphs that utilized data from all soil groups, i.e., residual, loessial, glacial, etc. The liquid limit relationship with the optimum moisture content again appeared to be the strongest of those investigated. Graphs of the activity coefficient, percentage fines, and percentage clay versus the optimum moisture content revealed only a slight relationship. The least significant graphs were those relating percentage sand and specific gravity to the optimum moisture content.

Graphs based upon data on soils from glacial areas revealed a somewhat different picture. The most significant graphs were those considering the optimum moisture content relationship with gradation characteristics, percentage sand, and percentage fines. The degree of linearity of the plasticity characteristics versus optimum moisture content graphs for glacial soils was slightly less than the graphs with gradation characteristics; however, the relationships revealed were significant.

The data from the Meramec Park Reservoir Project, presented in table V, were also plotted. These graphs were made to investigate the correlation potential of the soils within a very limited geographic area. These graphs show the optimum moisture content to be strongly related to activity coefficient, percentage sand, and percentage clay. The graph of optimum moisture content versus the specific gravity was of little importance. The most significant graphs are shown on figures 58 thru 65.

b. Maximum Dry Density. The graphs of maximum dry density versus the index properties considering all soil groups on one graph indicated good correlation with the plasticity indexes and only slight correlation with the percentage clay, percentage fines, and activity coefficient. The best correlation was with liquid limit, as can be seen by examination of figure 24. The least significant graph was with specific gravity. The graphs relating maximum dry density of residual soils with the plasticity indexes also revealed a strong linear relationship. The strength of the relationship appeared to be slightly better than the graphs utilizing data from all the primary soil groups. Again, the most direct relationship was maximum dry density with liquid limit. Those residual soil graphs of maximum dry density versus gradation characteristics, percentage sand, and percentage fines were only slightly significant. Graphs of maximum dry density versus gradation characteristics for glacial soils again revealed the gradation characteristics to be more prominent than the maximum density versus plasticity relationships. The most direct relationships were found with percentage fines, percentage sand, and liquid limit. The plastic limit and plasticity index graphs indicated only a slight relationship. The specific gravity and activity coefficient exhibited no tendency toward linearity.

Graphs of the Meramec Park data revealed good correlation of the maximum dry density with the plasticity indexes and less significant correlation with the gradation characteristics. The most important relationship was established with the liquid limit.

2. Shear Strength Parameters. Graphs of the consolidated drained shear strength parameters, ϕ and c, versus the index properties were not at all encouraging. The cohesion graphs with liquid limit, plastic

limit, plasticity index, optimum moisture content, maximum dry density, average water content, and percentage fines were found to be insignificant, except those graphs considering only glacial soil data. Examination of the glacial soil graphs revealed that the liquid limit, plasticity index, and the optimum moisture content graphs to be slightly significant. The cohesion versus plasticity index relationship was the strongest of those investigated. These graphs are presented on figures 27 thru 32.

The graph of the friction angle, ϕ, versus index properties was somewhat more promising. The relationship between the angle of friction and the plasticity index, liquid limit, optimum moisture content, maximum dry density, average sample water content, and activity coefficient was found to be significant. Surprisingly, the plastic limit graph was among the least significant of those made. As in the case of the cohesion graphs, the relationship of ϕ appeared to be strongest with the plasticity index.

The graphs of friction angle versus the gradation characteristics, percentage fine, percentage sand, and percentage clay for glacial soils were slightly more linear than the plasticity graphs. Although the gradation graphs were more significant, the degree of linearity of the graphs was not indicative of high prediction potential.

The information gained as a result of the graphical analyses proved to be very useful in focusing attention on those index properties of greatest importance. This knowledge was of great value in guiding the author's selection of variable combinations in the regression analysis which follows. The results of the graphical analysis have been tabulated in rating charts I, II, and III in order to facilitate review.

C. Regression Analysis.

1. General. Multiple linear regression analysis was used in this study to develop a variety of prediction equations which would relate the compaction and strength properties to their index properties. Many combinations of independent variables (index properties) were considered. Selection of the independent variables for each equation was made to achieve maximum prediction accuracy from the least amount of input data. Consideration was also given to the probable availability of test data in the office, field, and laboratory.

The regression analysis was performed on the UMR 360-50 IBM computer. A computer program entitled "Step-Wise Multiple Regression with Variable Transformations" was used to develop the desired equations. The Step-Wise Multiple Regression analysis is a computer procedure used to develop an equation for estimating one dependent variable by means of a linear combination of functions of several independent variables. The Step-Wise computer program operates on a batch of data to determine the linear parameters that best fit the data. The program has a built-in transformation system which can be employed by the programmer to transform the data into logarithmic, square, cubic, reciprocal, and many other forms. The pure data, along with the logarithm transformation, were used in this study to develop a series of arithmetic and logarithmic prediction equations. The investigator's choice of only the logarithm transformation was based upon consideration of both time and the broad scope of investigation. Consideration of some of the other transformations may prove fruitful in future correlation studies.

The Step-Wise program computes simple correlation coefficients for each dependent and independent variable in the analysis. Each variable, independent or dependent, is related to all other variables under consideration. This coefficient is a measure of the strength of the linear relationship between two variables. It should be understood that this is only a mathematical interpretation, and in no way reflects any cause or effect implication. The fact that two variables may be found to increase or decrease together does not necessarily imply that one has a direct effect on the other; however, such mathematical relationships can be utilized very effectively for prediction purposes.

The Step-Wise program will also compute the standard error of estimates for each equation developed. The standard error of estimate is a measure of the accuracy of the prediction equation. It can be used to make approximate probability statements about the error of prediction, provided the assumption that the normal distribution of error is found to hold. If this assumption is valid for a given error distribution, one can predict that 68% of the predicted results will be within one standard error and 95% of the results will fall within two standard errors of the actual values.

A total of 85 computer programs were utilized in this study. Fifty-three of these programs utilized the raw data without modification to develop a series of arithmetic equations. The other 32 programs employed the logarithm transformation ($\log_{10}$) to modify the data in order to obtain logarithmic equations. The analysis was conducted in stages so that the combination of independent variables (index properties) could be improved upon as the analysis proceeded. The correlation coefficients and standard error results proved to be very useful in establishing the combination of independent variables which offered the greatest prediction potential.

The final regression equations developed in the Step-Wise Regression Analysis are presented for both the arithmetic and logarithmic analyses on table VII. The correlation coefficients, standard errors, and scope considerations for each equation are also presented in table VII. Simple correlation coefficients between pairs of variables are presented for the most significant analyses on tables I thru IV. These results will be treated in detail in the discussion which follows.

2. Shear Parameters.

a. Cohesion. Nine programs were developed utilizing the cohesion parameters as the dependent variable and the index properties as the independent variables. The results of this analysis, as expected, based upon the cohesion graphs, were of little or no significance. This can readily be concluded by examining equations 1 thru 9 and their associated data in table VII. The correlation coefficients were found to not exceed .30 for all singular and multiple correlations considered except for those which focused only upon the soils of glacial origin. This was a direct indication of the poor mathematical relationship existing between this shear parameter and the index properties. The data on soils from glacial areas, when considered separately, were found to yield the greatest correlation coefficients for the cohesion versus index property relationships; however, the strength of the relationships as reflected by the correlation coefficients was not indicative of high prediction potential. The index properties which appeared to be most closely related to the cohesion parameter in all analyses, although not significantly, were the plastic limit, plasticity index, and average water content of the consolidated drained specimens. The correlation coefficients for analyses 1, 2, 8, and 9 are presented in table III to reflect the lack of significance of the relationship of the cohension parameter with the index properties and to show the increased strength of the correlation when the scope was limited to the data on samples taken from glacial soil areas.

Examination of the computed standard errors revealed that the accuracy of the prediction equation would be extremely limited. The probable errors in most cases would far exceed the allowable errors even in situations where rough approximations were desired. However, the standard error of the equation (equation 1) developed for the glacial soils was considerably less than the errors of equations developed from all soil or residual soil considerations. This equation, c =.010 + .005 - .003 Opt. + .001PL, could therefore be used to estimate the cohesion parameter of glacial soils. Since the standard error of the partial equation, c = -.025 + .005PI, developed in this analysis, does not exceed the error of the final glacial equation, prediction can be justifiably based upon the plasticity index alone. This equation has been plotted on the graph of cohesion versus plasticity for glacial soils, figure 50. The use of this equation should be limited to glacial soils and to those situations where precise estimates are not required. Sixty-eight percent of the results based upon this equation may be expected to have errors not exceeding .06 TSF or 120 PSF.

b. Angle of Internal Friction. The angle of internal friction was found to be more closely related to the index properties than the cohesion shear parameter. Nine arithmetic and nine logarithmic regression analyses were performed to investigate the various data categories. Fourteen of these programs utilized the data as a whole, while the remaining four considered the residual and glacial soil data separately.

These analyses revealed that the scope of consideration was of little importance in determining the relationships of the friction angle and the index properties. All analyses yielded results which were very consistent. The all soil, residual, and glacial considerations indicated that the relationship of the angle of friction with the plasticity index, liquid limit, activity coefficient, optimum moisture content, maximum dry density, and the average water content of the direct shear specimens were all significant. Although the relationships with these variables were determined to be significant, it must be pointed out that the magnitude of the correlation coefficient was not indicative of a high degree of correlation. The best correlation in all cases was achieved with the plasticity index. The correlation of ϕ with the activity coefficient and the plastic limit was far below the significance level.

The arithmetic and logarithmic equations developed in this series of analyses are presented on table VII, equations 26 thru 34 and 26A thru 34A. Note the combinations of independent variables considered in these equations. The standard error and correlation coefficients are also presented on table VII. These results show that several procedures can be employed to predict the angle of friction within a reasonable degree of accuracy. The simplest procedure would be to utilize equation 31,

$$\phi = 34.5 - .37(PI) + .04(W.C.),$$

for all soils except those of glacial origin. Assuming the error distribution to be normal, one could expect approximately 70% of the predictions based upon this equation to be within 4 degrees of the actual values. This accuracy would be acceptable for all but the most precise determinations. The regression equations developed for glacial soils was found to be somewhat more accurate than the equations developed for either the all soil or residual soil considerations. These equations, 26 and 26A, would permit prediction of the friction angle of glacial soils within an accuracy of about 3 degrees.

Complex equations involving more than one independent variable were also developed to increase the prediction accuracy. Of this type, equations 28, 33, 28A, and 33A were the most efficiently developed. Examination of the computer output data revealed that the standard error was only slightly reduced as additional index properties were incorporated in the regression equation. In all cases the plasticity index was the first independent variable to enter the multiple regression equation; the standard error reduction beyond this point was not significant. Therefore, it appears reasonable to make estimates to ϕ based solely upon the plasticity index in lieu of the more complex equations which require several index properties. Therefore, it is recommended that equations 26, 28, 33, 26A, 28A, and 33A be modified by eliminating all terms except the constant and plasticity index terms in order to simplify the prediction requirements without greatly sacrificing the prediction accuracy. These equations would then be written:

$$(26)\ \phi = 34.04 - .58\ (PI)$$
$$(28)\ \phi = 26.8 - .31\ (PI)$$
$$(33)\ \phi = 25.1 + .03\ (PI)$$

$$(26A)\ \log \phi = 1.88 + .14 \log (PI)$$
$$(28A)\ \log \phi = .59 - .21 \log (PI)$$
$$(33A)\ \log \phi = 1.61 - .04 \log (PI)$$

Use of the above simplified forms should not result in more than four degrees error in approximately 68% of the predictions.

3. Compaction Properties.

a. Optimum Moisture Content. The optimum moisture content was found to be related to many of the index properties. The most important relationships were with the plasticity indices, percentage of clay, and the maximum dry density. Less significant relationships were established between the optimum moisture content and the activity coefficient, percentage of sand, and percentage of fines. The only index considered which did not appear to be slightly related to the optimum moisture content was the specific gravity. The equations developed in the regression analysis which express these relationships are equations 35 thru 52 and 35A thru 51A. Simple correlation coefficients for analyses 35, 36, 48, 49, and 51 are shown in table IV.

When all soils were considered in the regression analysis, it was determined that the highest degree of simple correlation with the optimum moisture content could be achieved with the liquid limit and maximum dry density. The correlation coefficient computed for both of these properties was about .90, which was indicative of a nearly linear relationship. The standard error for the developed maximum density and liquid limit equations was about ±1.20 and ±2.00 respectively in both the arithmetic and logarithmic regression analyses. These equations, 41, 41A, 42, and 42A, could therefore be used to estimate the optimum moisture content with a high degree of accuracy. Equations 41 and 42 have been constructed on figures 11 and 22, respectively. These constructions shown on these figures can be used in combination to effectively predict the Proctor moisture and density. For example, if limit data are available, one can utilize the liquid limit in conjunction with the graph on Plate 11 to evaluate the optimum moisture content; and then use this value in the determination of the maximum density from figure 22.

The other plasticity indices can also be used to predict the optimum moisture content, although with a lesser degree of accuracy. The error resulting from the regression equations 44 and 44A, which included only the plasticity index, was slightly greater than that of the liquid limit equations 41 and 41A. Use of plasticity equations 44 and 44A would increase the range of possible error approximately five-tenths of a moisture point. Although somewhat accurate estimates of the optimum moisture content can be made by using the plasticity index in this equation, its use will probably be limited due to the increased error of prediction and its intimate relationship with the liquid limit. The optimum moisture content versus plastic limit relationship was found to be least significant of those relationships developed from the plasticity indices. Equation 43, which employs only the plastic limit to predict the optimum moisture content, can be used to predict within an accuracy of ±3.4 moisture points approximately 70% of the time; however, for many prediction situations, this accuracy would not be sufficient.

The gradation characteristics, percentages of clay, fines, and sand, were all found to be related to the optimum moisture content in the all soil analysis; however, the correlation coefficients, presented in tables I thru IV, revealed a very low level of significance for all but the percentage of clay. The percentage of clay regression equations 46 and 46A can be used to predict the optimum moisture content in cases where the required accuracy is not great. Consider the laboratory technician who must perform the standard compaction tests with no guidance as to what moisture to prepare the compaction specimen other than the results of the mechanical analysis. Here is a situation where precise prediction is not required, and equations 46 and 46A could prove to be very useful tools. In order to make use of the other gradation characteristics, percentage of fines and percentage of sand, complex equations employing many variables would be required to minimize the error of prediction.

Regression analyses were also performed to develop a series of complex equations to better the optimum moisture content prediction accuracy. Many combinations of index properties were employed in these analyses as can be seen from examination of the resulting equations 35 thru 40 and 35A thru 40A. The standard error of these equations was considerable less than that of the simple equations discussed above. Equations 35, 36, 38, and 40 are the most accurate of the equations developed. The choice of the equation to be used in predicting the optimum moisture content will largely be dependent upon the availability of test data because the difference in the standard error of estimates of these equations is not great. Equations 35, 36, 38, and 40 can be used to predict the optimum moisture content within an accuracy of about ± 2 moisture points, which would be well within the range of allowable error of most prediction situations. A convenient three variable graph has been developed based upon equation 52 relating the optimum moisture content to the liquid limit and plasticity index. This graph is presented on figure 67. The choice of equation 52 was based upon error considerations and the advantage of developing these relationships on the Casagrande plasticity chart. This graph has an added advantage over graphs similar to the Yemington graph, figure 7, in that it ties in graphically the optimum moisture content relationship with the other well established facts regarding the plasticity chart, especially those facts regarding compressibility, permeability, rate of volume change, and dry strength. One can now readily see the increase and decrease in the optimum moisture content with corresponding increases and decreases in the plasticity index and liquid limit. It would appear that graphs of this type will greatly facilitate the engineer's understanding of facts regarding the plasticity chart.

When the computer analysis was limited to soils of a particular area or to those of similar origin, the optimum moisture content-index property relationships were found to be very similar to the optimum moisture content-index property relationships when all the soils data were utilized in a single analysis. However, other importance findings did result from these analyses. Five categories of data were considered in these computer analyses:

(1) Residual soils.

(2) Glacial soils.

(3) Coastal plains soils.

(4) Soils encountered on the projects of the St. Louis District Corps of Engineers.

(5) Soils encountered on the Meramec Park Project.

The soils encountered on projects of the St. Louis District included glacial, residual, and recent alluvium deposits. The data on soils from the Meramec Park Project included residual soils and alluvial flood-plain deposits.

The results of the regression analyses considering residual soils, St. Louis District soils, and the Meramec Park soils separately were almost identical to the results of the analysis reported above, which utilized all test data; however, the correlation coefficient and standard error were both indicative of a much stronger relationship between the optimum moisture content and index properties. This conclusion was drawn from the examination of the correlation coefficients and standard error of estimates of equations 47, 48, 50, 47A, and 50A. A number of factors including the data categories under consideration both with respect to origin and geographic area and the difference in the number of observations used in these analyses may have contributed to this slightly higher degree of correlation. It should be noted that the residual, St. Louis District, and Meramec Park regression analyses were based upon 120, 59, and 20 data observations; whereas, the analyses utilizing all the test data in a single regression analysis were based upon observations numbering over 300.

The regression analyses on soils of glacial origin and soils of the coastal plains revealed the gradation characteristics to be just as prominent in predicting the optimum moisture content as the plasticity characteristics. Analyses 49, 49A, and 51 indicated the percentage of fines and percentage of sand to have very significant correlation coefficients, especially in the case of the soils of the coastal plains. The standard error of these equations 49, 49A, and 51 was indicative of a very high degree of accuracy. The standard error in these analyses was approximately ± 1.4, which meant that about 70% of the predicted values of the optimum moisture content would not deviate more than ± 1.4 moisture points from the actual optimum moisture content, and that about 95% of the results would not deviate more than ± 2.6 moisture points. Although these equations reflect a high potential for accurate prediction, their use should be limited to the soils of glacial origin and to soils of the coastal plains. In no case should these equations be used without establishing their validity for the soils of a particular area.

b. Maximum Dry Density. Twenty-seven regression analyses were performed to determine a series of arithmetic and logarithmic equations which could be used to estimate the Proctor maximum dry density. The results of these analyses were very consistent with the results of the optimum moisture content regression analyses. The correlation of the maximum density with the plasticity indices and the percentage of clay was again found to be most prominent. The activity coefficient, percentage of fines and the percentage of sand based upon computed correlation coefficients were only slightly related to the maximum density. The results of the maximum density versus specific gravity analysis were the least significant of those considered. The correlation coefficients, standard error, and the equations developed in these analyses are presented on table VII.

Initially, 10 equations were developed using one independent variable (index property) per equation to approximate the maximum density. These analyses considered all the soil data without regard to origin or geographic area. The developed equations are numbered 14 thru 19 and 14A thru 19A, on figure 70. Simple correlation coefficients for the most significant analyses are presented in table II. The most precise arithmetic and logarithmic equations were 14 and 14A, respectively, which related the maximum density and liquid limit. Equation 14 has been constructed on the graph of maximum density versus liquid limit, figure 55. Based upon this equation, the maximum density could be predicted with an accuracy of about ±4.0 pounds, one standard error. This accuracy would be tolerable for most prediction situations; however, many field situations would require even greater accuracy.

Several complex equations employing more than one variable were developed to increase the maximum dry density prediction accuracy. Many combinations of index properties were considered in the analysis in order to derive the most efficient relationships. Equations 10 thru 13, 15, 15A, 25, and 25A resulted from this series of regression analyses. In only two of these equations, 10 and 11, was the standard error reduced significantly. One could expect about 70% of the predictions based upon equations 10 and 11 to be within 3.6 pounds of the actual maximum dry density.

Equation 15 was used to develop a graph of maximum dry density versus the liquid limit and the plasticity index. This graph was made on a chart similar to the conventional plasticity chart. The advantages of charts of this type have been reflected earlier in the discussion covering the optimum moisture content. The standard error which may result from use of this chart as a predicting aid should not exceed ±4.1 pounds for 70% of the density predictions.

In addition to analyses considering all soil data, five other data categories were investigated to determine the correlation potential of soils of similar origin and those within a limited geographical area with the maximum dry density. The geographic and origin considerations were the same as those investigated in the optimum moisture content analysis. The results of the regression analysis on the St. Louis District soils, Meramec Park soils, and the residual soils were, as before consistent with the results of the all soil analysis. The liquid limit again was the most significant relationship, as can be seen by examining equations 20, 21, 23, 20A, and 23A in the regression summary. The correlation coefficients and the standard error of the developed regression equations were indicative of a more linear relationship between the maximum dry density and liquid limit than in the regression analysis utilizing all data collectively. These equations can be used to predict the maximum density with accuracy that exceeds that of any equation developed in the previous analysis which considered all data collectively; however, the index data required to evaluate these equations may limit their use. Examination of the computer output data revealed that significant changes in the standard error resulted as each index property entered the partial regression equation; therefore these equations could not be modified without greatly sacrificing the prediction accuracy.

The regression analysis on soils of the coastal plains and soils of glacial areas indicated the gradation characteristics to be slightly more prominent than the plasticity characteristics in predicting the maximum dry density. The correlation coefficients for the percentage of sand and percentage of fines were slightly greater than those of the plasticity indices. The standard error of the resulting regression equations, 22, 24, 22A, and 24A, was approximately ± 3.5 pounds. This error would be allowable for most prediction situations.

Again, it must be emphasized that use of the equations developed in this study should be limited to the areas of consideration for which they were developed, and only then after the validity of the equations has been established through check procedures.

IV. ERROR ANALYSIS

Two of the prediction equations developed in this study were tested with data taken from the second Bureau of Public Roads Report[10] which was discussed in Section II. The data consisted of Atterberg limits and standard Proctor compaction results on 100 soil samples from widely separated areas throughout the United States. Selection of the data was based upon complete coverage of the soils of the major soil groups; i.e., residual, glacial, loessial, coastal plains, and soils of the filled valleys. The data have been tabulated in tables V and VI. Examination of these tables will reveal the wide variation in plasticity and compaction characteristics of those samples considered.

The equations selected for this investigation were developed in regression analyses 52 and 53. These equations,

$$\text{Maximum Density} = 128.4 - .58LL + .13PI$$

and

$$\text{Optimum Moisture Content} = 6.228 + .3411LL - .1062PI$$

were selected for this analysis because they are considered to be among the most prominent equations developed in this study. They could rapidly be evaluated from available data; and, because they were used in the development of the plasticity versus compaction relationships presented on <u>figures 65</u> and <u>67</u>, the lack of sufficient data and the complexity of some of the more accurate equations precluded their use in this investigation of error.

Two equations were evaluated for each of the 100 data observations presented in tables VI and VII. The predicted values of the optimum moisture content and dry density, along with the deviation from the actual laboratory results, are also presented in tables VI and VII.

The optimum moisture results (evaluation of equation 52) show that the predicted values of 85 percent of the observations did not exceed ±2 moisture points, and that 67 percent of the predicted values did not exceed the actual laboratory result by more than ±1.5 moisture points. The standard error of estimate for the 100 deviations was ±1.67 moisture points. This means that if the normal distribution of error holds--and if the 100 soil samples used were entirely representative--that 68 percent of the results should be within 1.67 moisture points of the actual values.

Examination of the predicted evaluation of equation 53, and the actual laboratory densities revealed that 55 percent of the results deviated less than ±3 pounds and that 71 percent deviated not more than ±4 pounds. The standard error for this analysis was ±3.9 pounds.

To relate the error in the maximum dry density with the error in the optimum moisture content, percentage error computations were made. These computations were based upon the average of the optimum moisture content, percentage error computations were made. These computations were based upon the average of the optimum moisture and maximum dry density of the 100 observations. The ratio of the respective standard errors to these averages revealed that the percentage error of the optimum moisture was about 9 percent, whereas the error in the dry density amounted to only 3.6 percent of the average dry density. So it would appear that the accuracy of dry density equation, equation 53, was somewhat better than that of the optimum moisture equation, equation 52.

In order to verify that the standard error of estimate was a reasonable measure of the error in these prediction equations, and to validate the probability statements regarding the error of prediction that have been made throughout Section III, the deviations (actual-predicted) were plotted to establish the distribution of error. The distribution plot of the optimum moisture deviations revealed an approximately normal distribution, as can be seen by examining figure 68. The typical normal distribution of the deviations from the maximum dry density is shown on figure 69. This double peaked distribution deviated considerably from the normal distribution; however, this does not void the probability statements made earlier regarding the error of the dry density prediction equations. The double peaked distribution may be the result of several factors including the effect of two competing normal distributions and nonrepresentative data. Even though the exact cause of this distribution cannot be readily determined, the author has concluded that the standard error of estimate is a reasonable measure of the accuracy of both the optimum moisture content and dry density equations. This conclusion is based upon a comparison of the actual deviations in table V with the computed standard error of estimate. This comparison revealed that about 70 percent of the predicted values was less than the standard error, which is a very close approximation of the 68 percent boundary defined by the standard error of estimate.

The error of the developed cohesion and friction angle equation was not investigated here because of inadequate data. It is therefore recommended that use of the shear equations developed herein be limited to situations where only rough approximations are required or where sufficient data are available to validate the equations and associated statements of probable error.

V. CONCLUSIONS

This study has served to substantiate many of the known relationships between the engineering properties and their index properties, and to more accurately define these relationships. The data furnished in Section III are conclusive evidence of the existing interrelationships between the compaction properties, consolidated drained shear parameters and their index properties. The more significant findings are summarized below:

(1) Only a slight correlation of the cohesion drained shear parameter with index properties could be achieved.

(2) The angle of internal friction for drained shear could be significantly correlated with all index properties except the plastic limit and activity coefficient.

(3) The best correlation of both shear parameters was achieved with the plasticity index.

(4) The maximum dry density and optimum moisture content were found to be strongly related to the plasticity characteristics and only slightly related to the gradation characteristics, except for glacial soils. The most direct relationship was generally determined to be with the liquid limit.

(5) The shear parameters and compaction properties of glacial soils appeared to be more significantly related to the gradation characteristics than the plasticity characteristics, as evidenced by the computed correlation coefficients.

This study has also provided useful information regarding the importance of scope considerations in relating engineering properties to their index properties. It appears that considerably better correlation can be achieved by limiting the scope of consideration to soils of similar origin or to soils of a limited geographic area. This study revealed a much greater prediction accuracy for all analyses where the scope was so limited. It is therefore concluded that future efforts in this area should be concentrated on the soils of the individual soil groups or those within a very limited geographic area, if maximum correlation is to be achieved.

Useful equations and prediction procedures have been developed in this study. These equations have been tested and found to be sufficiently accurate to warrant their use in many prediction situations. The author is confident that these developments will prove to be useful tools to those working in the field of soil mechanics and other allied fields.

VI. APPENDICES

APPENDIX A

GRAPHICAL ILLUSTRATIONS

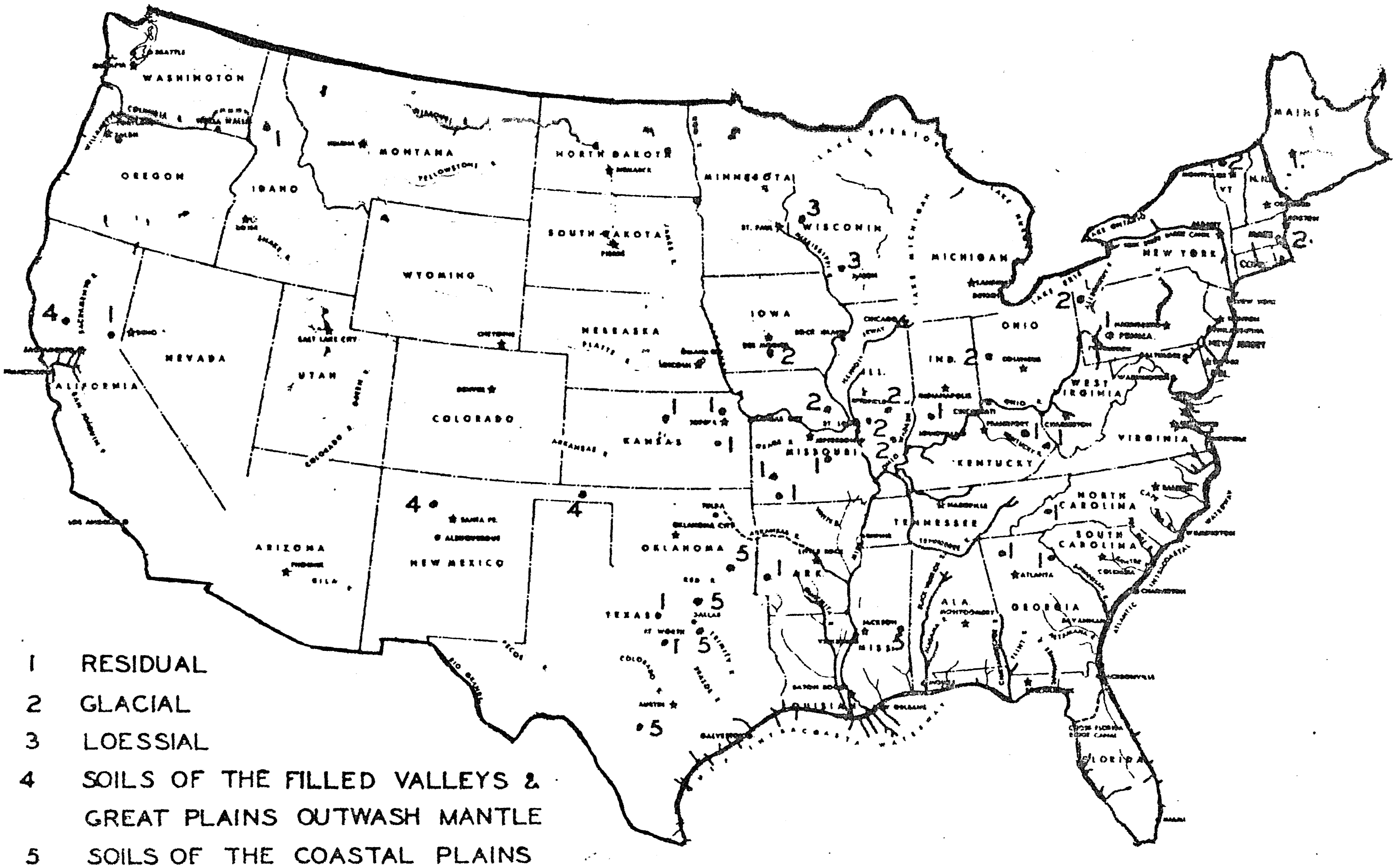
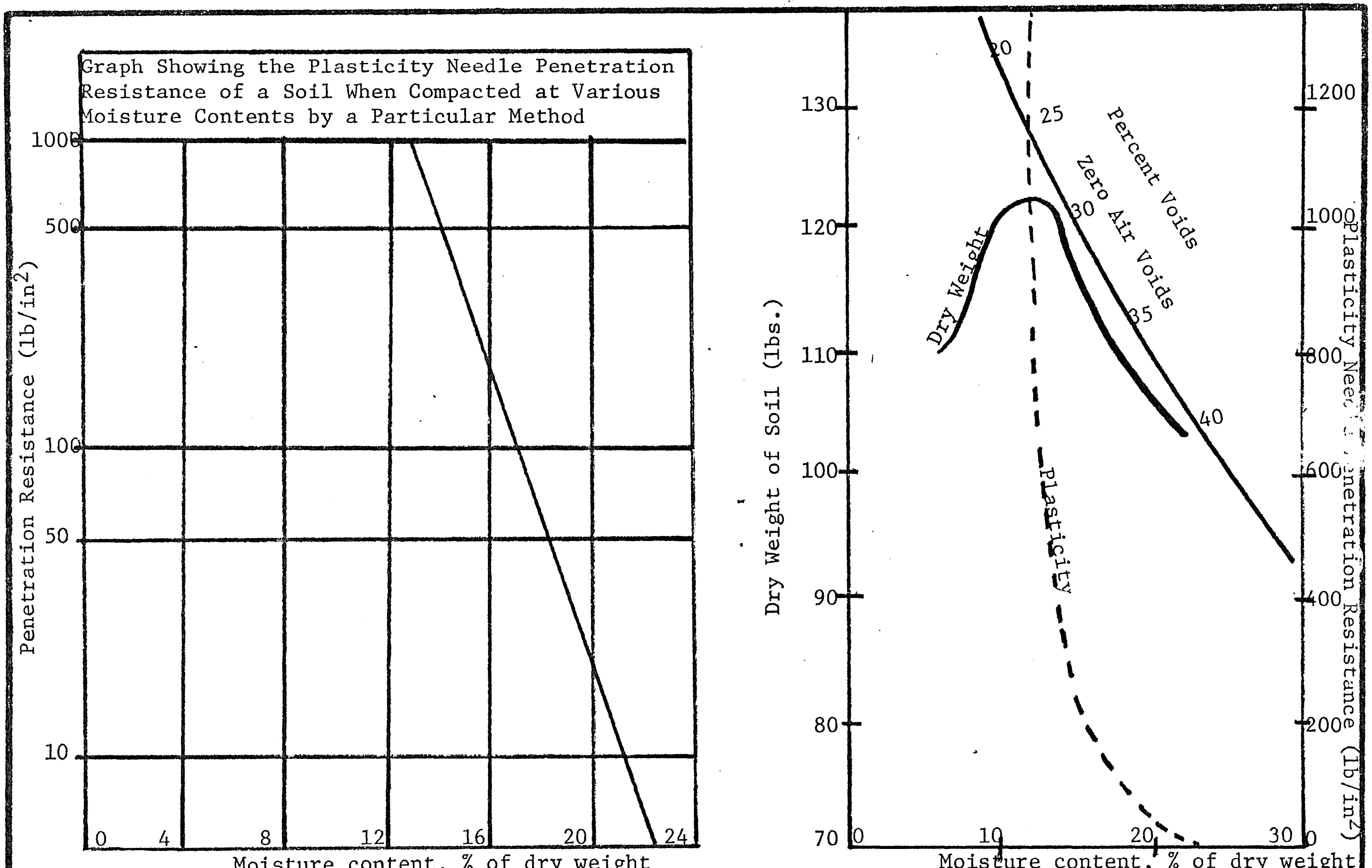


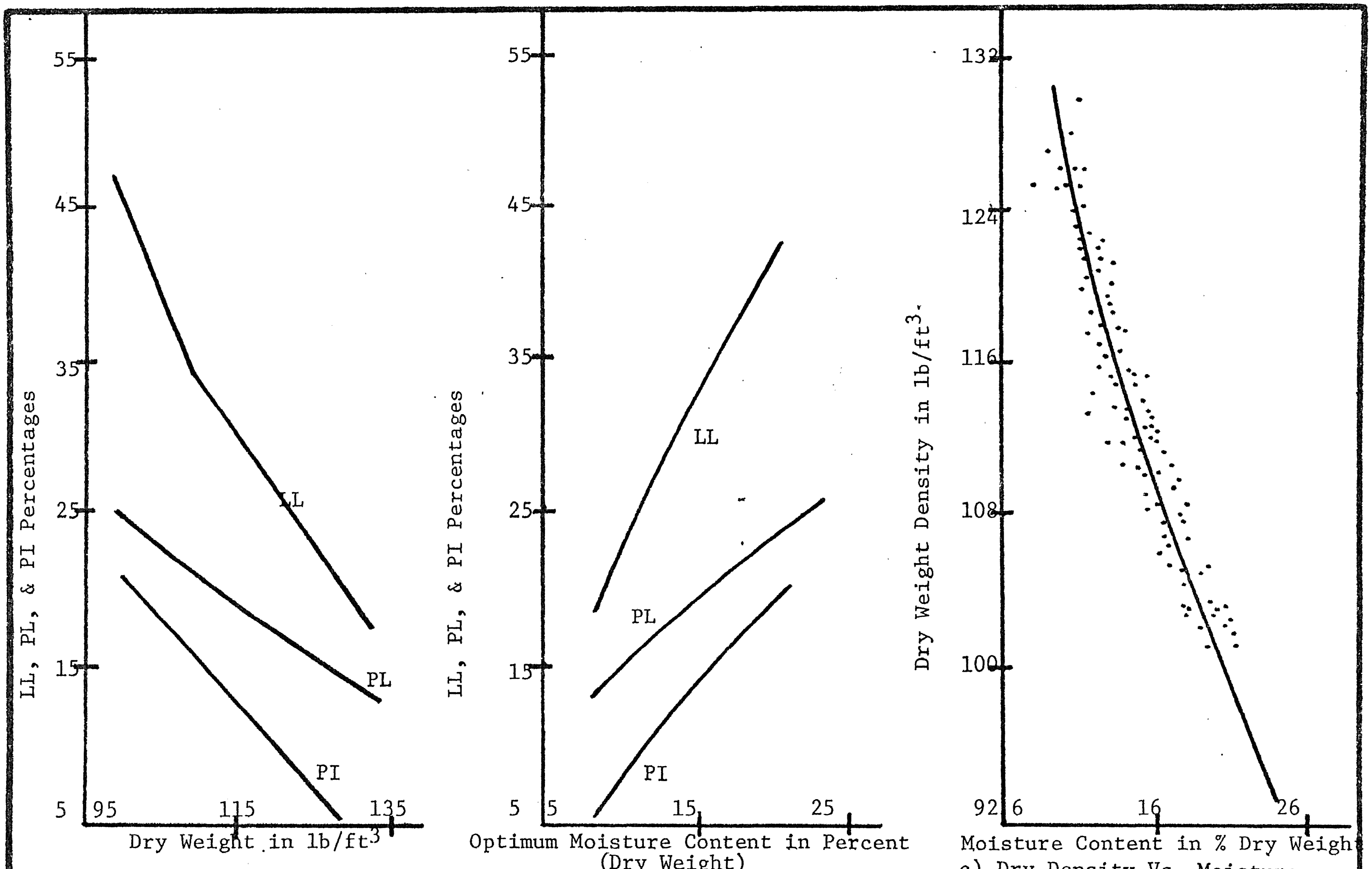
Figure 1. Geographic Map Showing Soil Sampling Locations



a) Plasticity Penetration Resistance vs. Moisture Content

b) Soil Characteristics Curves

Figure 2. Proctor Plots (after Proctor 1933)



a) LL, PL, & PI Vs. Dry Density b) LL, PL, & PI Vs. Opt. Moisture c) Dry Density Vs. Moisture Content

Figure 3. Ohio State Engineering Experiment Station-Graphical Plots (after O.S.U., 1938)

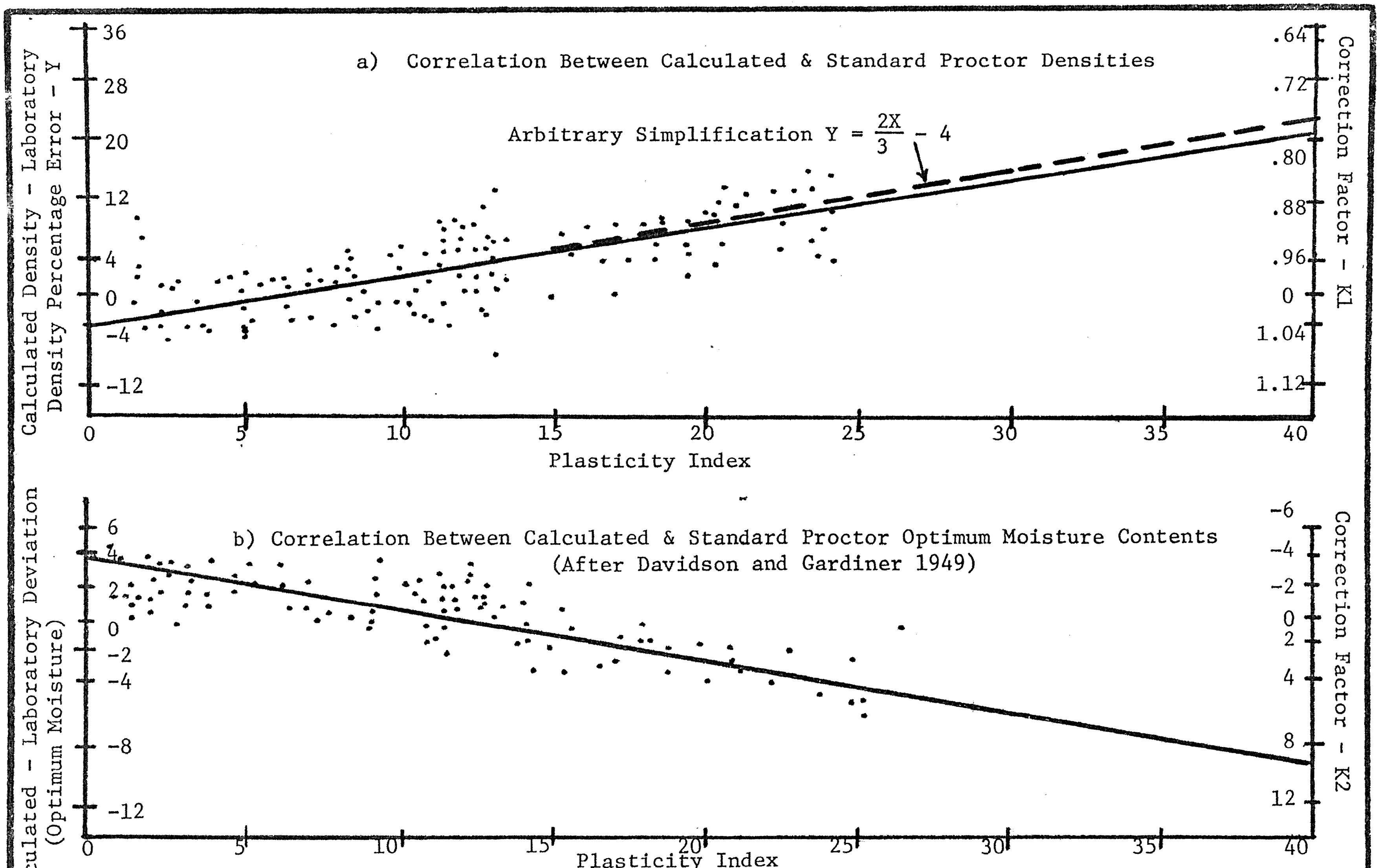


Figure 4. Davidson and Gardiner Plots of Prediction Error vs. the Plasticity Index (after Davidson and Gardiner)

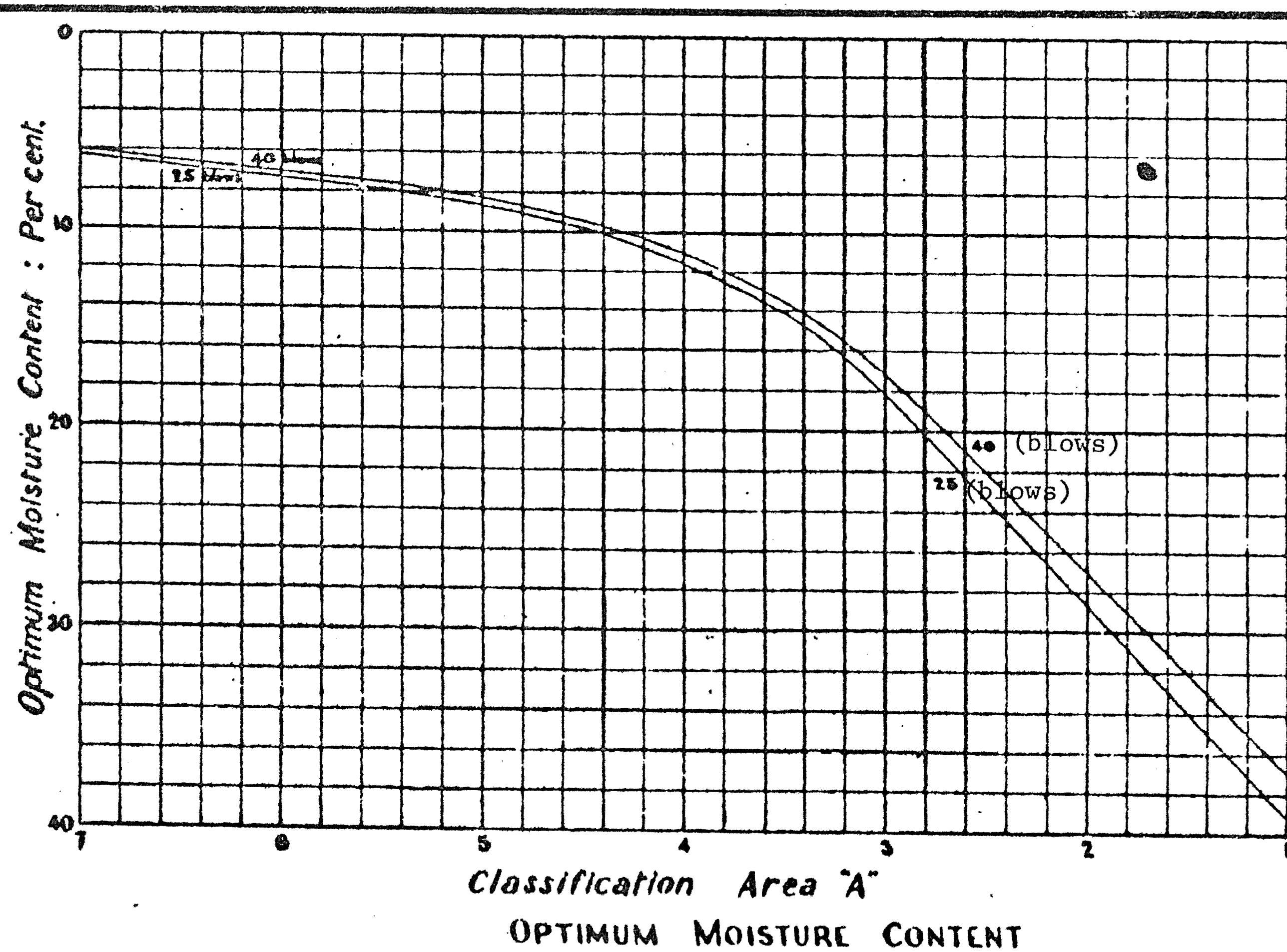


Figure 5. Graph of Optimum Moisture . .(after Turnbull 1948)

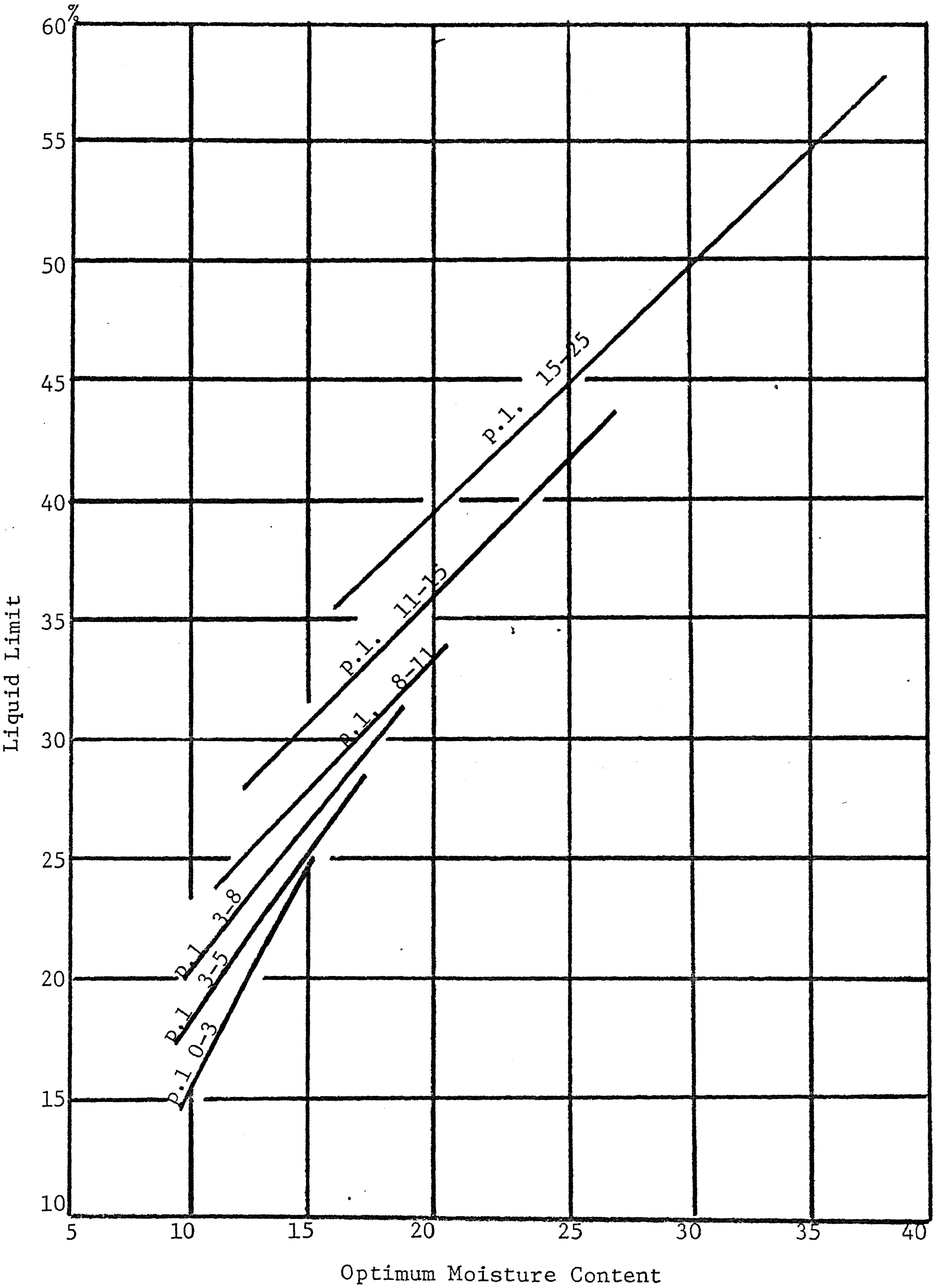
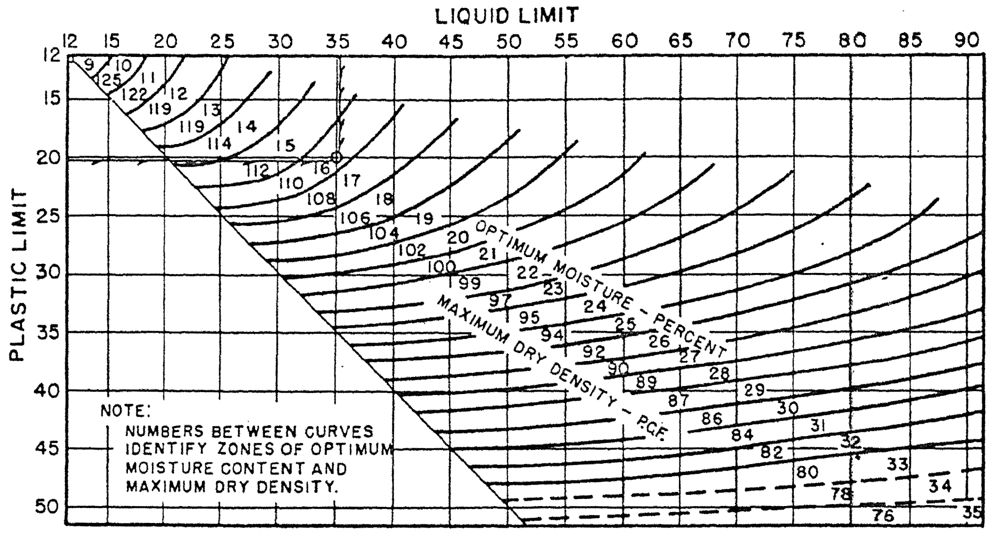
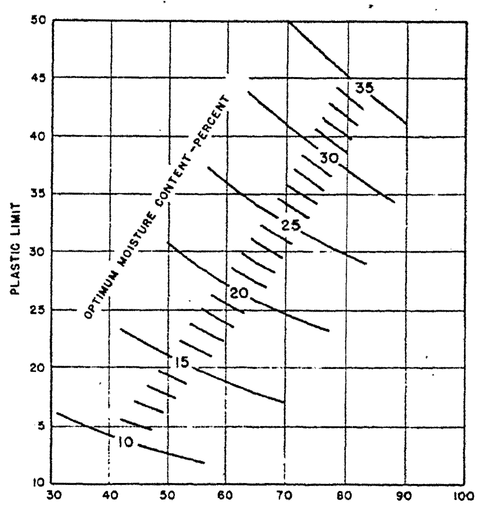


Figure 6. Plot of Liquid Limit Versus Optimum Moisture Content (after Jumikis 1958)

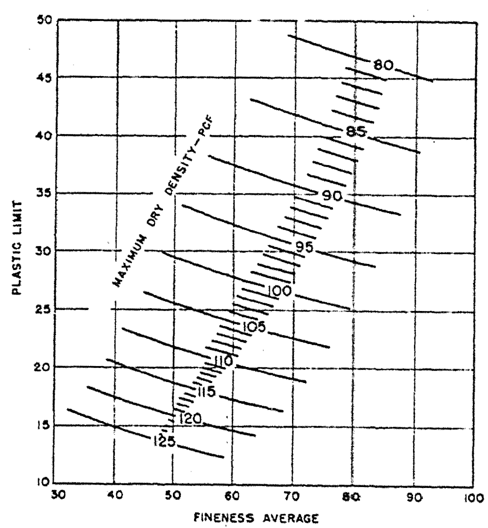


Example: Given: Plastic limit - 20 Liquid limit - 35 Find: Average maximum dry density and optimum moisture content.
Answer: 110 p.c.f. density and 16 percent moisture.

a) *—Relation of average maximum dry density and optimum moisture content to plastic limit and liquid limit.*



b) *—Relation of optimum moisture content to plastic limit and fineness average, analysis No. 4.*



c) *—Relation of maximum dry density to plastic limit and fineness average, analysis No. 8.*

Figure 7. Bureau of Public Roads Charts (after B.P.R. 1962)

State	Predominant soil type* (origin)[1]	No. of samples for which the estimated optimum moisture content was less than the test result by amount indicated												No. of samples for which the estimated optimum moisture content exceeded the test result by amount indicated					
		−11	−10	−9	−8	−7	−6	−5	−4	−3	−2	−1	0	+1	+2	+3	+4	+5	+6
Alabama	Residual	----	----	----	----	----	----	----	----	----	----	3	16	12	1	----	----	----	----
Arizona	do	----	----	----	----	----	1	1	2	1	----	----	2	----	----	----	----	1	----
Arkansas	Recent alluvium	----	----	----	----	----	----	----	1	1	2	4	10	8	2	----	----	----	----
Connecticut	Glacial	----	----	----	----	----	----	----	1	1	1	4	7	2	2	1	----	----	----
Florida	Coastal plain sand	----	----	----	----	----	----	----	----	1	1	1	3	4	1	----	----	----	----
Idaho	Non-soil	1	1	2	----	----	4	5	4	4	6	11	20	9	2	----	3	----	1
Illinois	Loessial	----	----	----	----	----	----	----	----	----	1	10	12	5	----	----	----	----	----
Kentucky	Residual	----	----	----	----	----	----	----	----	1	----	6	18	4	1	----	----	----	----
Maryland	do	----	----	----	----	----	----	----	----	----	2	3	6	7	3	1	2	----	----
Minnesota	Glacial	----	----	----	----	----	----	----	2	4	4	4	3	2	1	----	----	----	----
Nebraska	Outwash	----	----	----	----	----	----	1	1	7	7	7	15	7	4	1	1	----	----
Nebraska	Loessial	----	----	----	----	----	----	----	----	2	4	13	8	----	1	----	----	----	----
Nevada	Non-soil	----	----	1	1	2	1	1	2	1	----	----	----	----	----	----	----	----	----
New Mexico	Residual	----	----	----	----	----	----	----	----	----	1	2	4	1	2	----	----	----	----
North Carolina	do	----	----	----	----	----	----	----	----	----	1	3	5	5	1	2	----	1	----
North Dakota	Glacial	----	----	----	----	----	----	1	2	2	2	2	4	4	2	----	----	----	----
Oregon	Non-soil	----	----	----	----	1	2	2	1	1	1	2	7	----	3	----	----	----	----
Tennessee	Residual	----	----	----	----	----	----	1	3	----	10	11	7	6	----	----	----	1	----
Texas	Coastal plain clay	----	----	----	----	----	----	----	----	----	----	2	7	1	2	----	1	----	----
Texas	Residual	----	----	----	----	----	----	----	1	1	2	----	----	1	2	----	----	----	----
Vermont	Glacial	----	----	----	----	----	----	1	----	1	----	3	4	7	----	----	----	----	----
Ohio	Lacustrine	----	----	----	----	----	----	----	1	----	1	1	2	2	----	----	----	----	----
Totals		1	1	3	1	3	8	13	21	28	46	92	160	87	30	5	7	3	1

Summary of Deviations of Optimum Moisture Contents Estimated by The PL and LL CHART (figure 7) From Those Determined by Test.

Figure 8. Bureau of Public Roads Prediction Deviation Table (after the B.P.S. 1958).

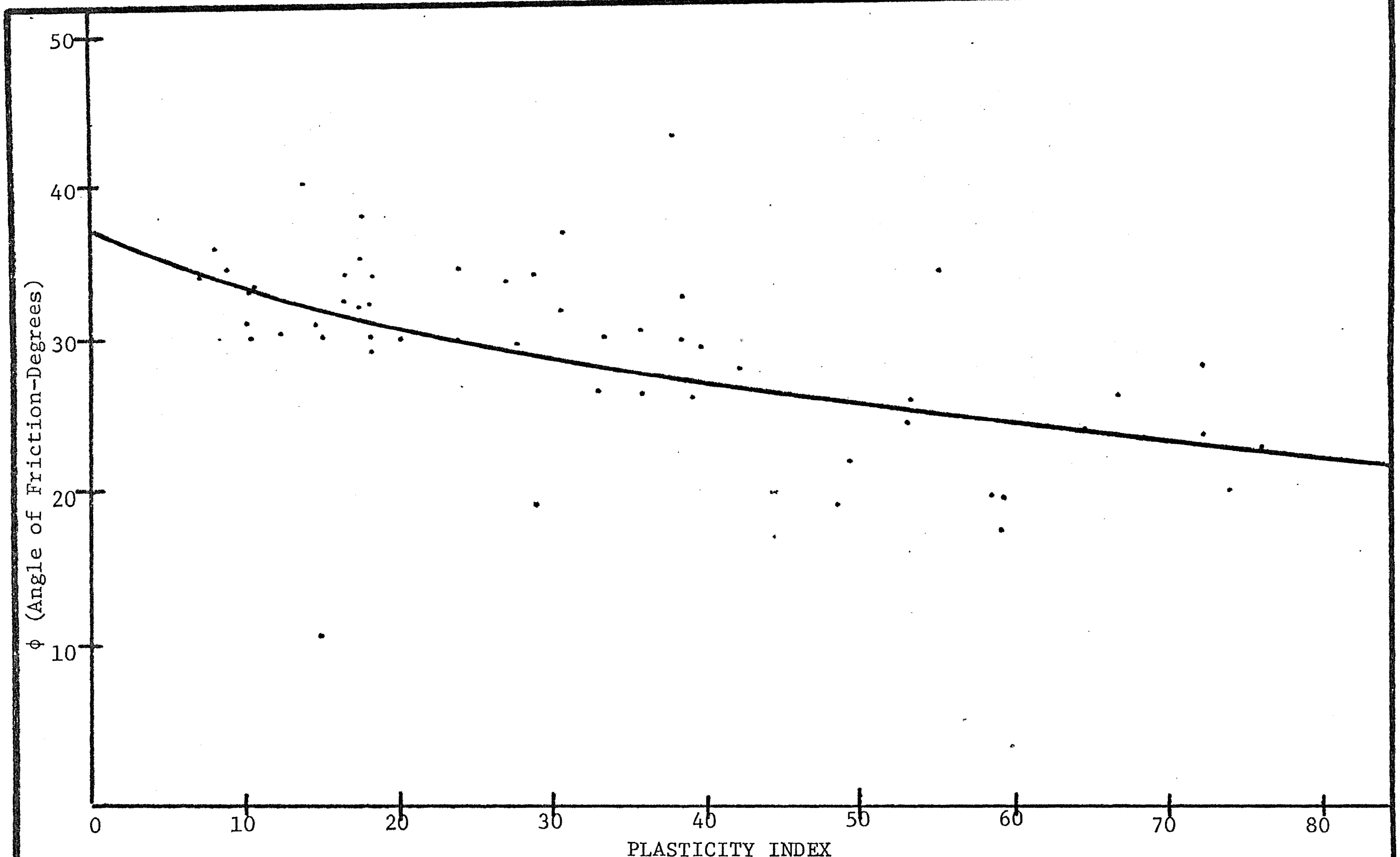
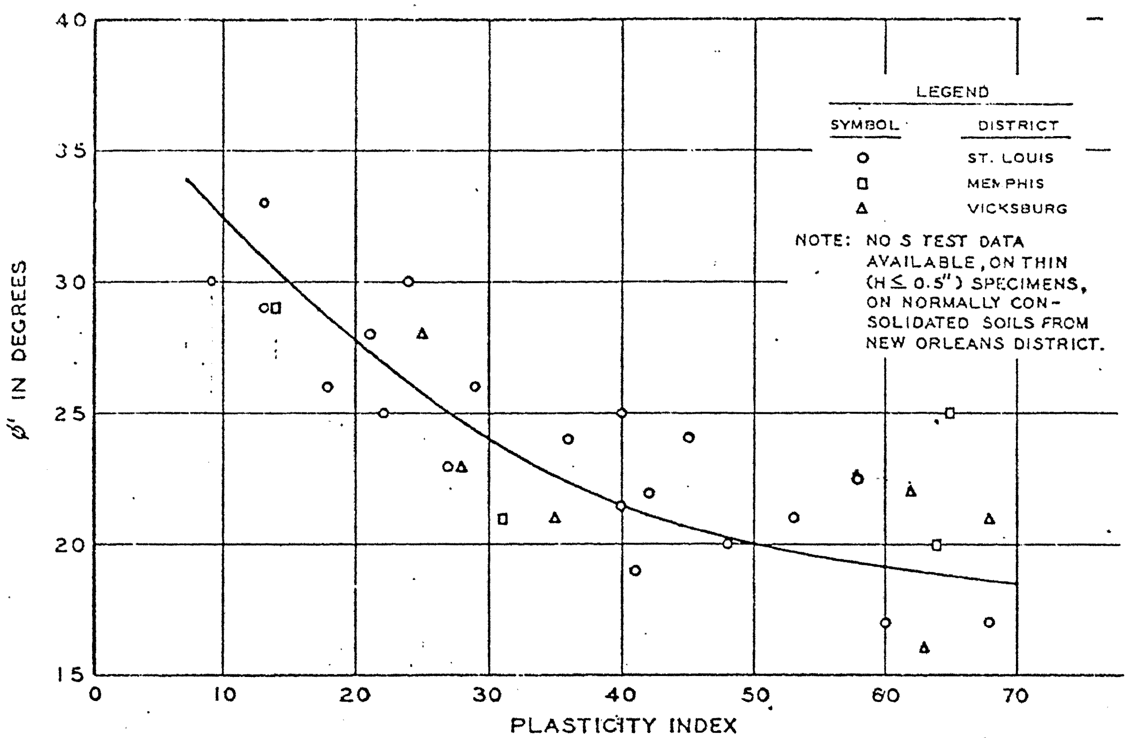
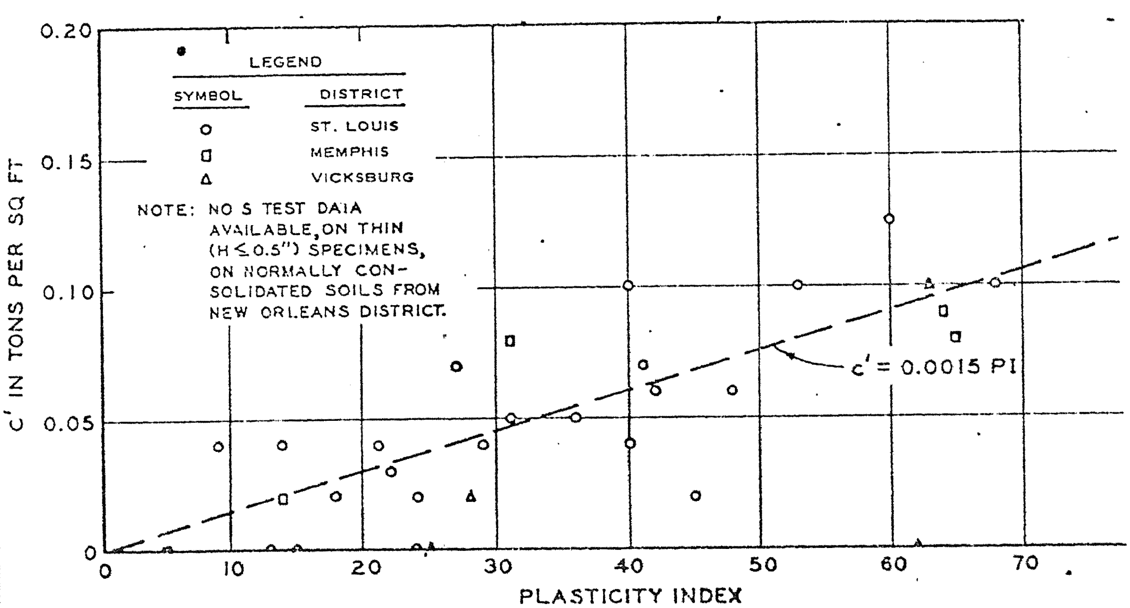


Figure 9. Bjerrum and Simon's Plot of Consolidated Drained Angle of Friction Versus Plasticity Index



a) Consolidated Drained Angle of Friction Versus Plasticity Index



b) Cohesion Versus Plasticity Index

Figure 10. U. S. Army Corps of Engineer Plots (after the Corps of Engineers 1962)

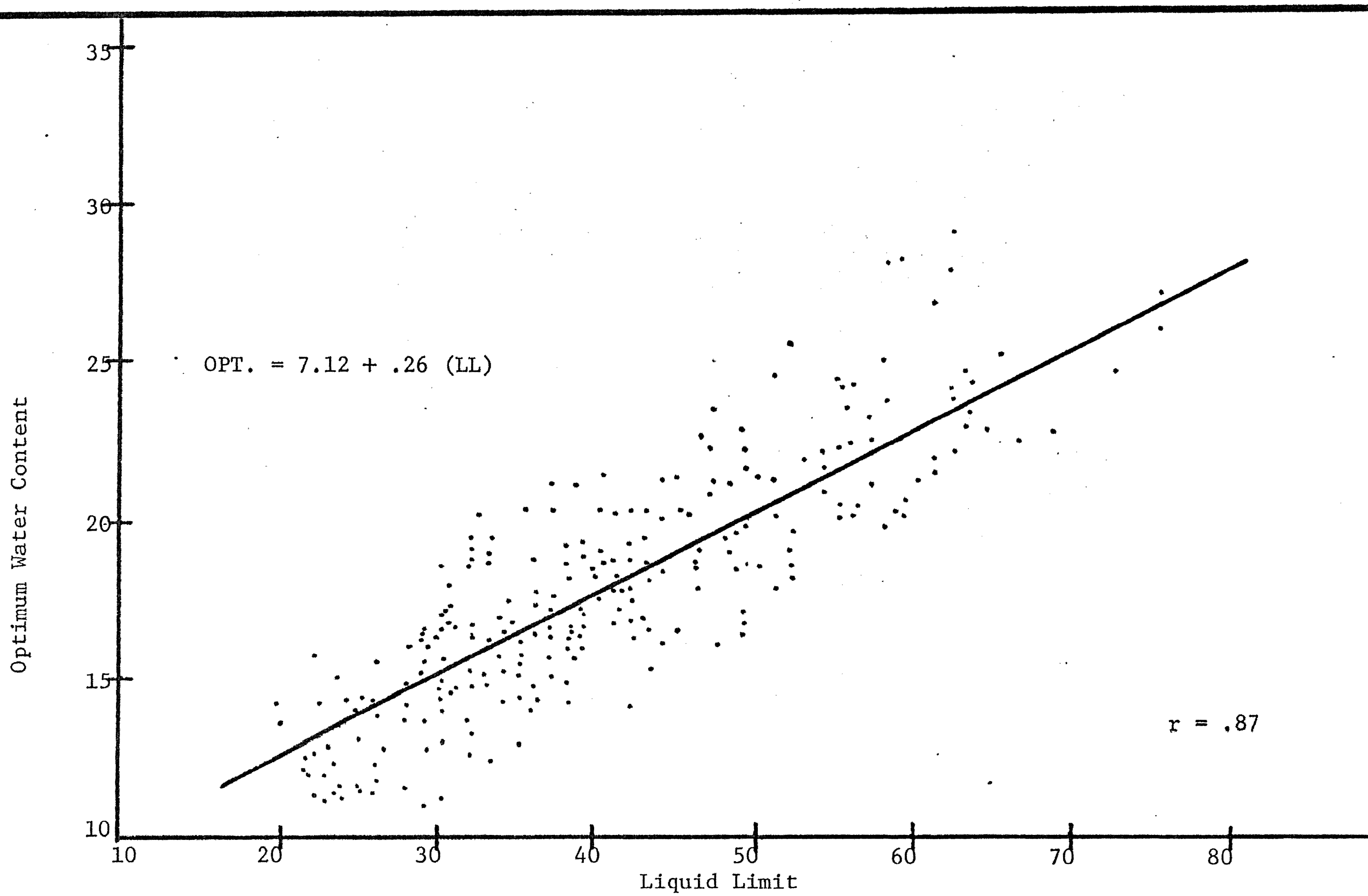


Figure 11. Optimum Moisture Content Versus Liquid Limit
(All Soils Arithmetic Plot)

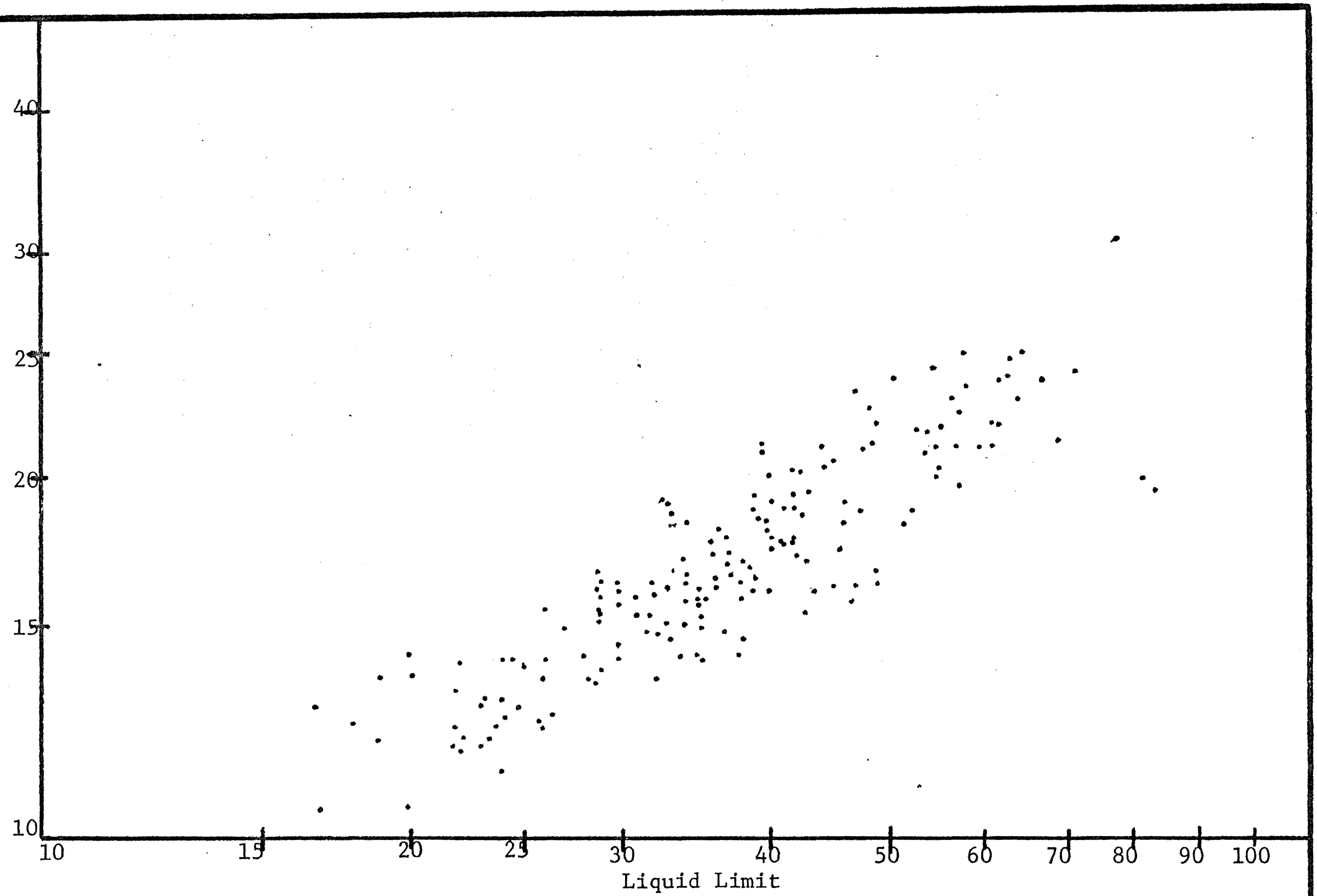


Figure 12. Optimum Moisture Content Versus Liquid Limit
(All Soils - Logarithmic Plot)

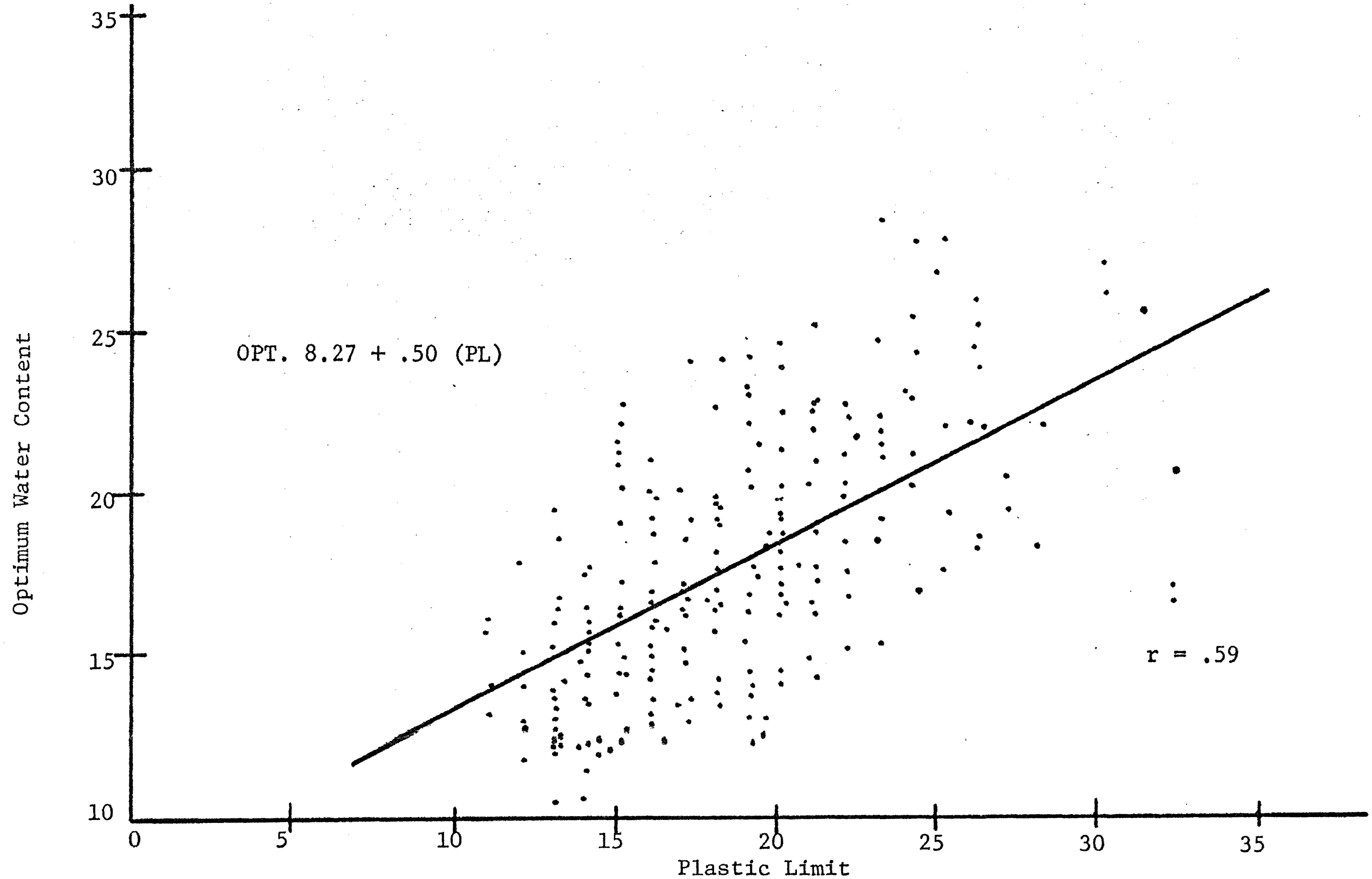


Figure 13. Optimum Moisture Content Versus Plastic Limit
(All Soils - Arithmetic Limit)

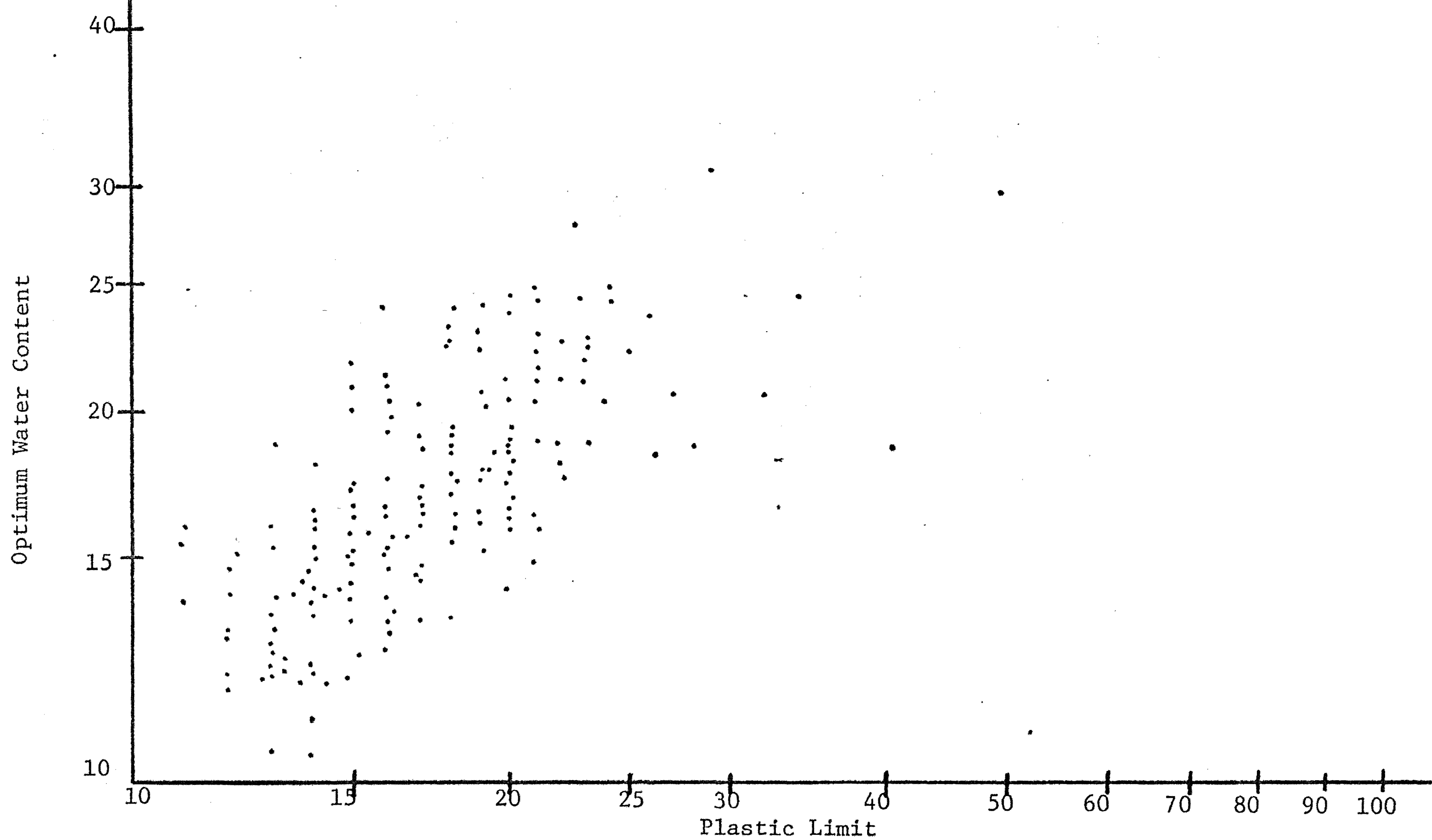


Figure 14. Optimum Moisture Content Versus Plastic Limit
(All Soils - Logarithmic Plot)

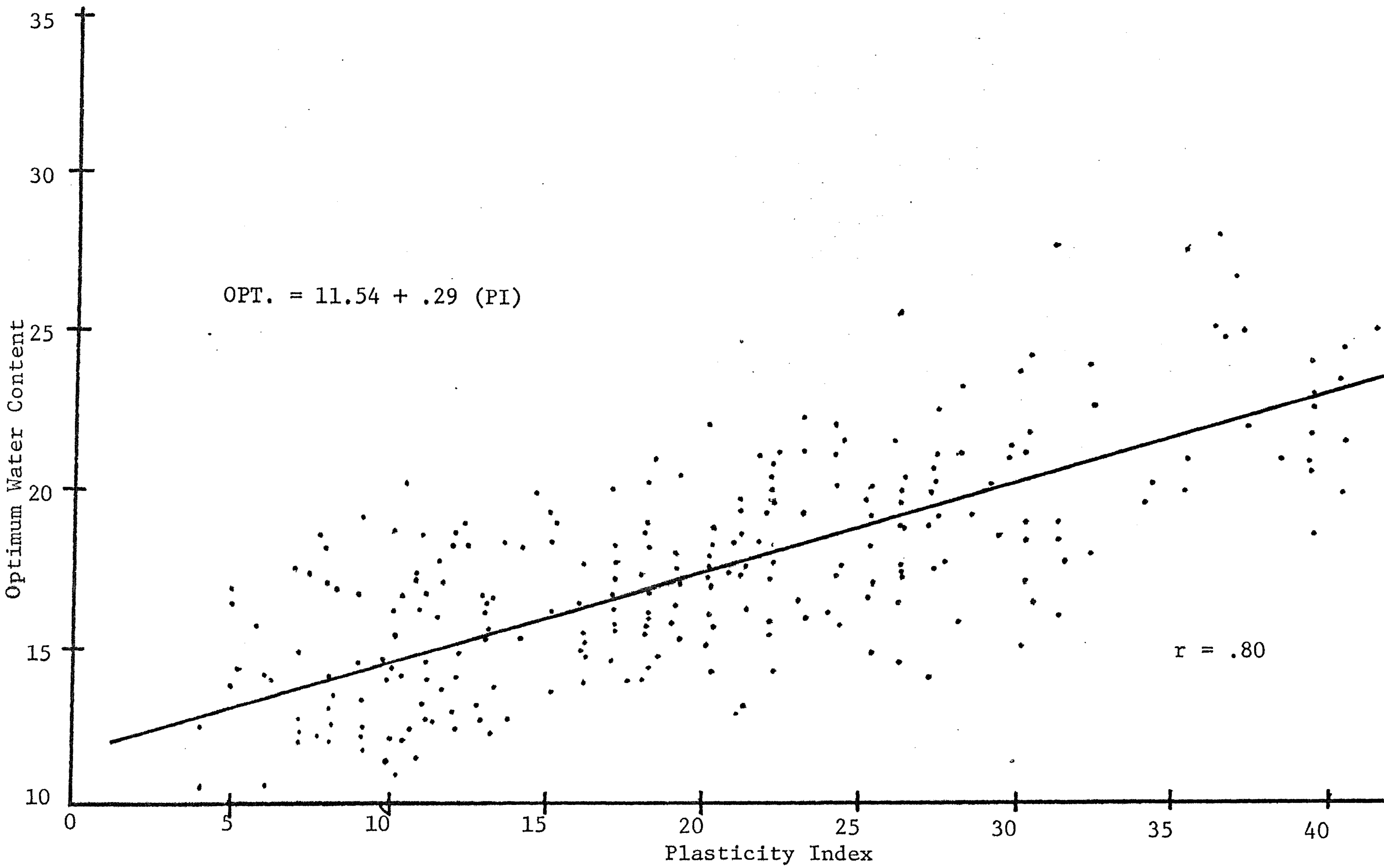


Figure 15. Optimum Moisture Content Versus Plasticity Index (All Soils - Arithmetic Plot)

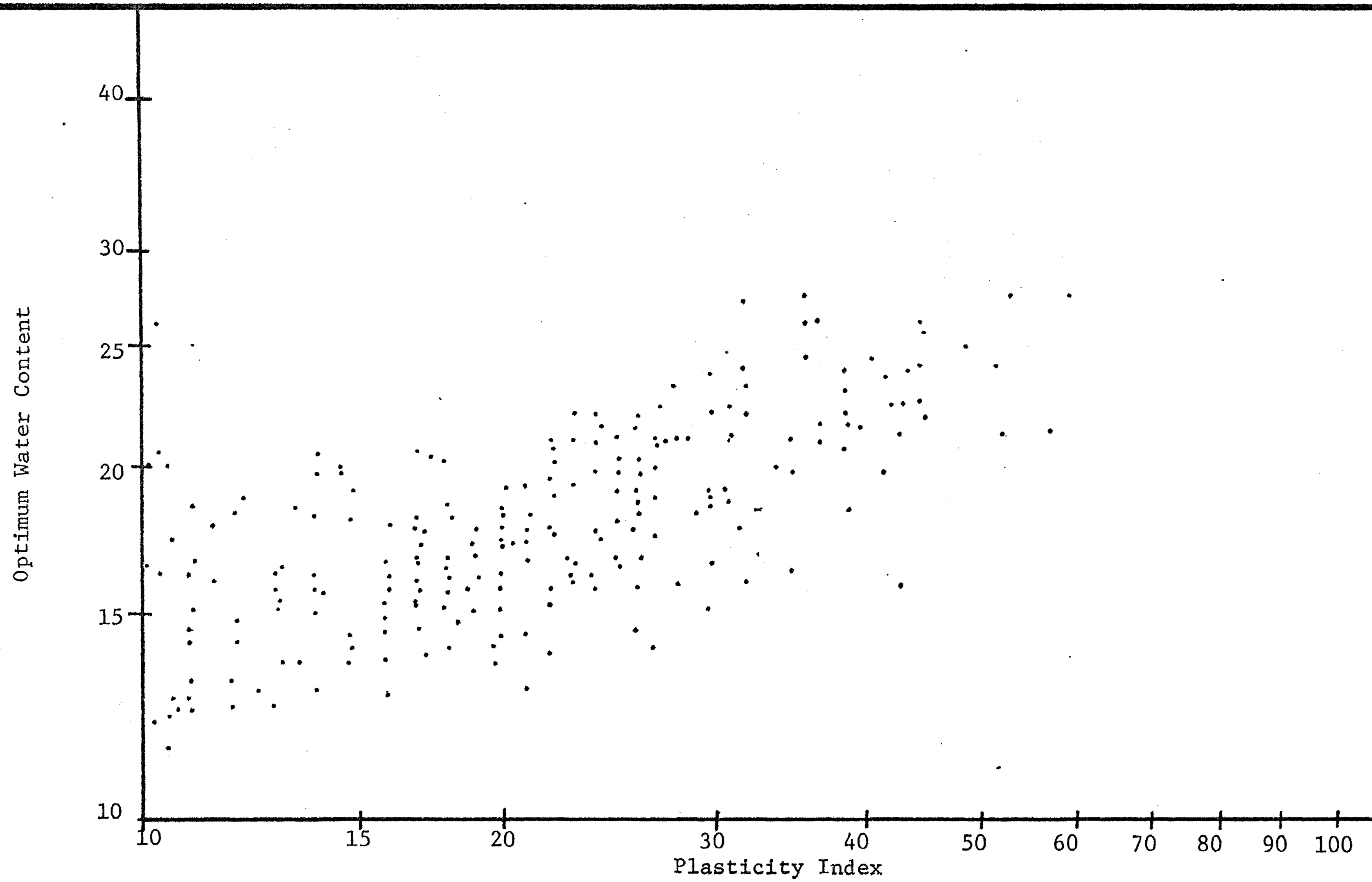


Figure 16. Optimum Moisture Content Versus Plasticity Index
(All Soils - Logarithmic Plot)

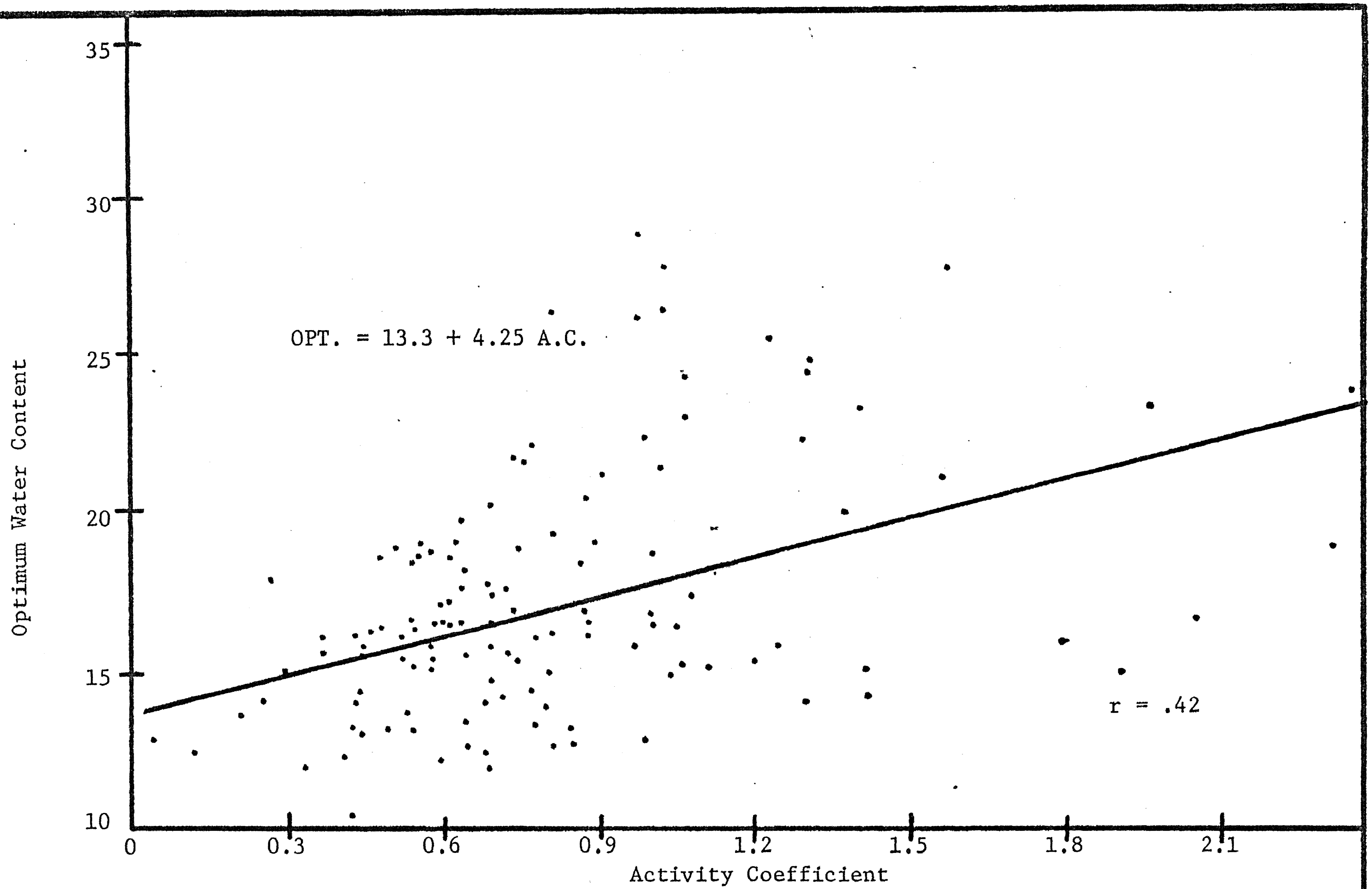


Figure 17. Optimum Moisture Content Versus Activity Coefficient (All Soils - Arithmetic Plot)

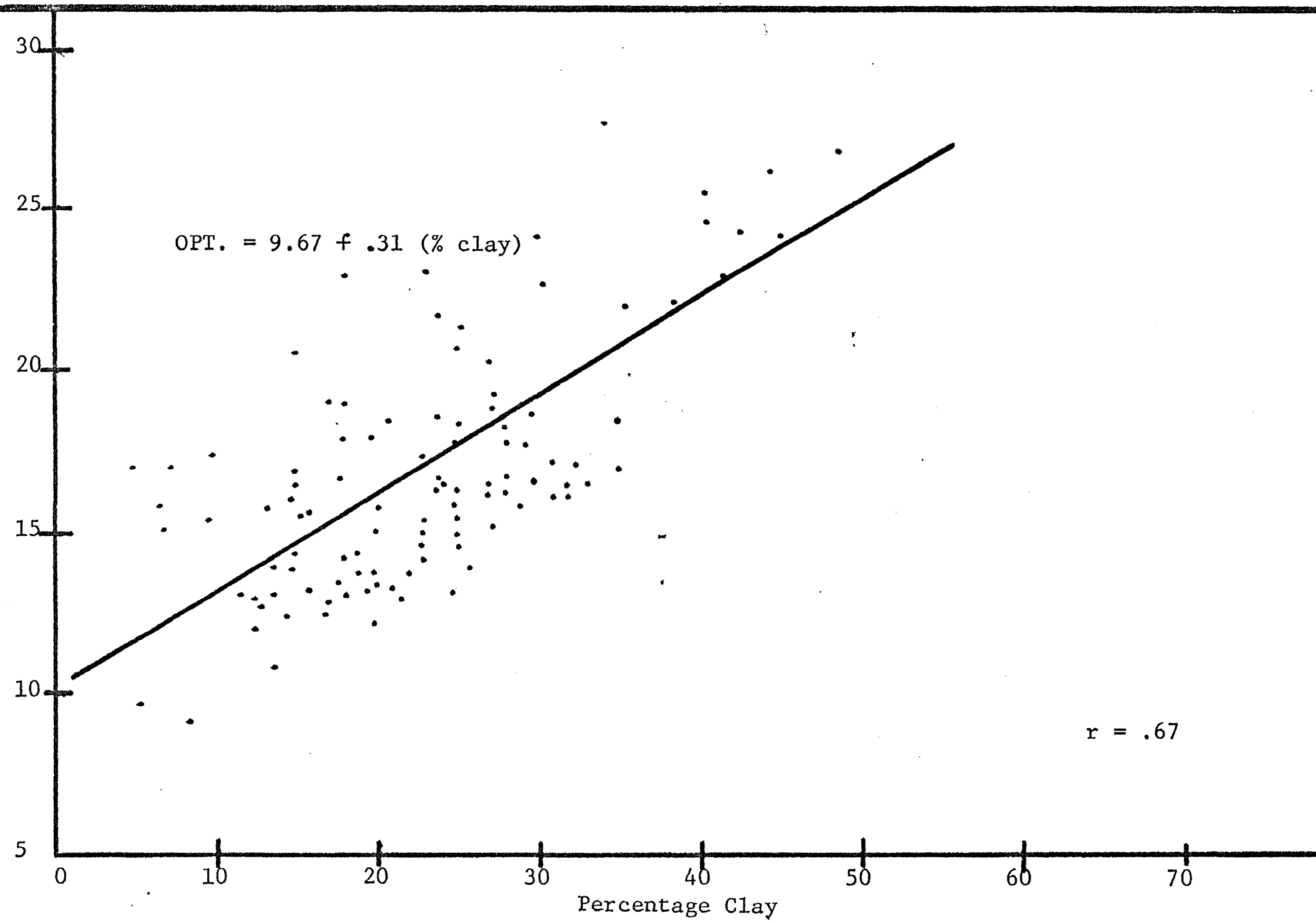


Figure 18. Optimum Moisture Content Versus Percent Clay
(All Soils - Arithmetic Plot)

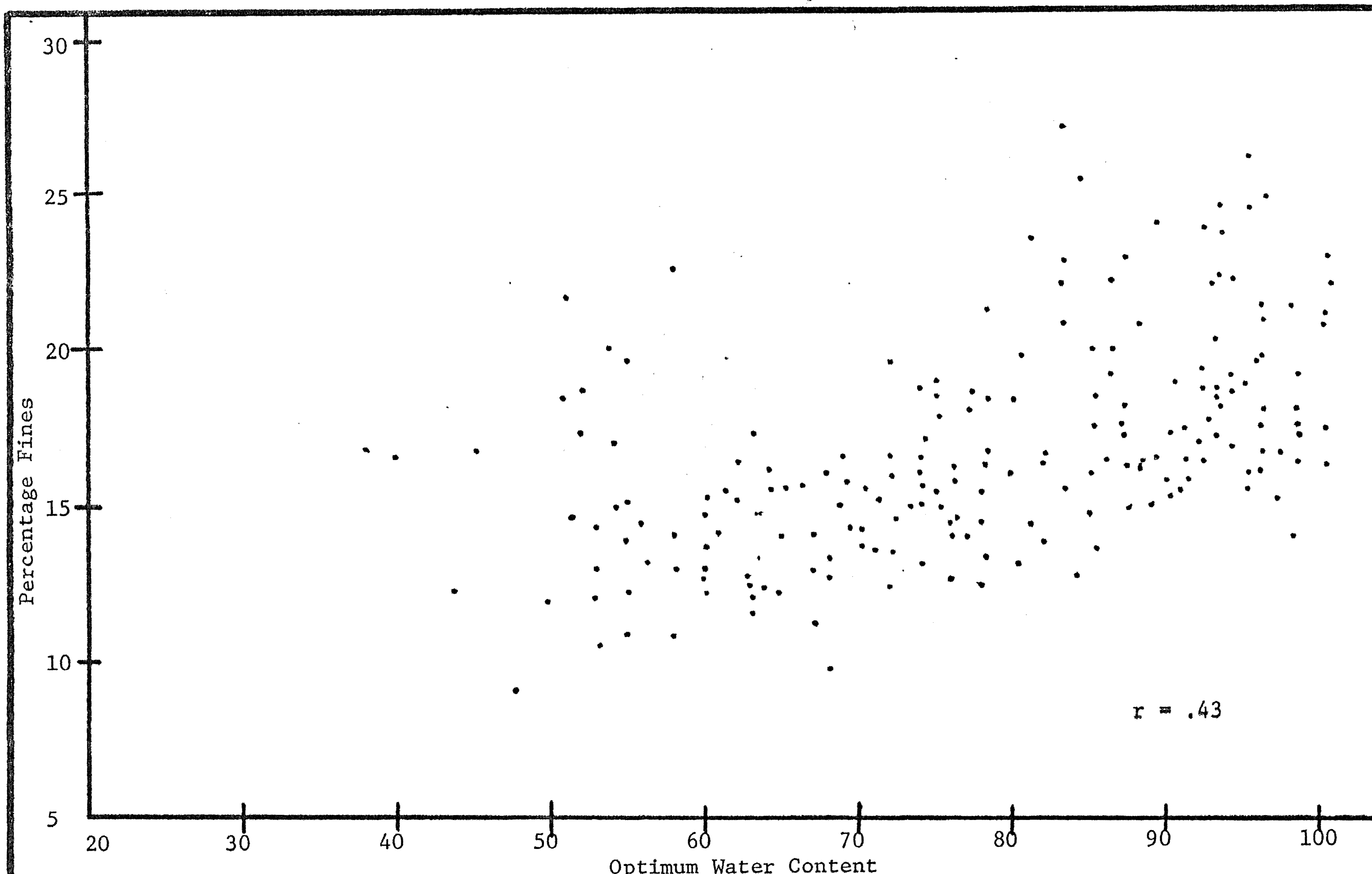


Figure 19. Optimum Moisture Content Versus Percent Fines (All Soils - Arithmetic Plot)

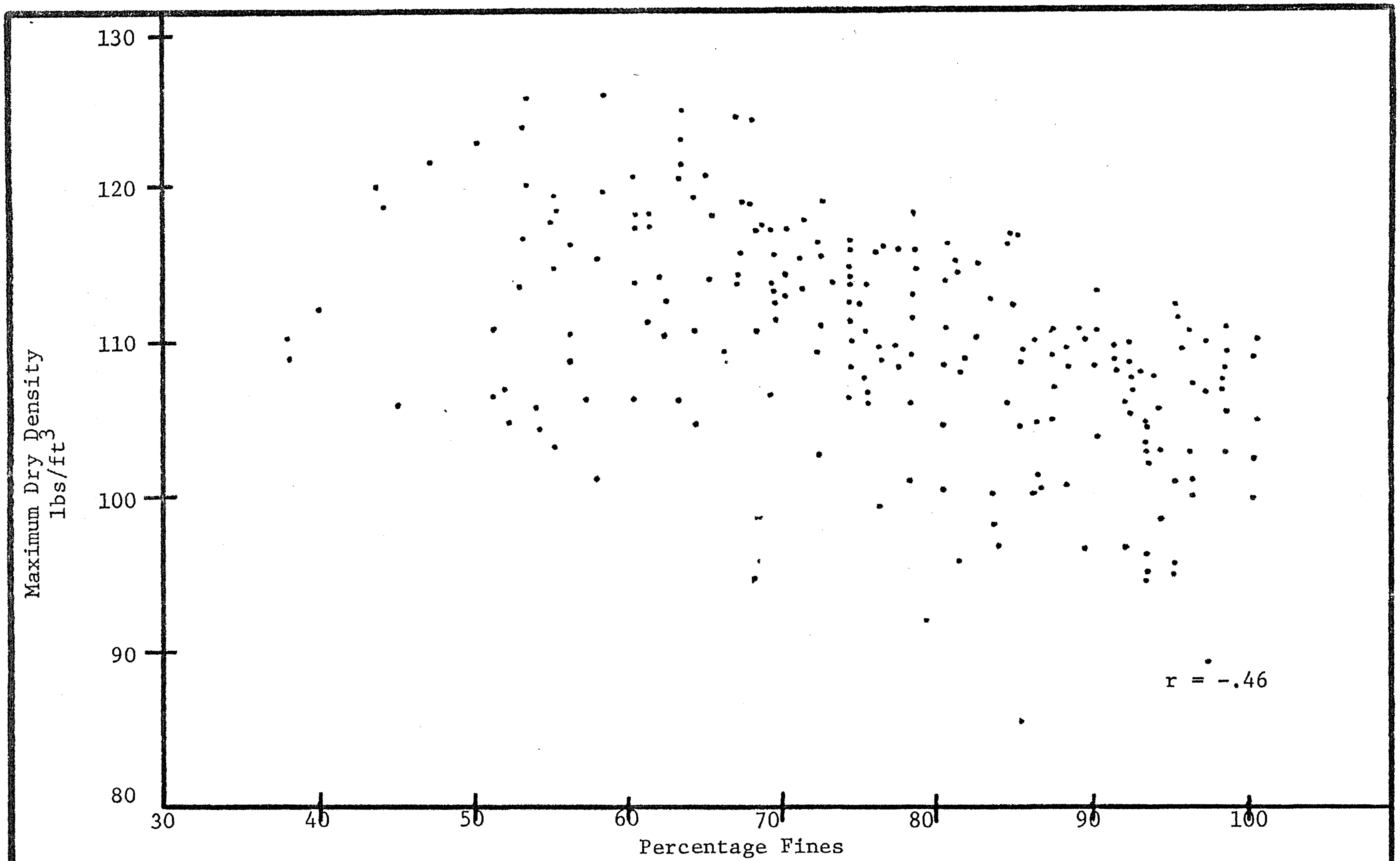


Figure 20. Maximum Dry Density Versus Percent Fines
(All Soils - Arithmetic Plot)

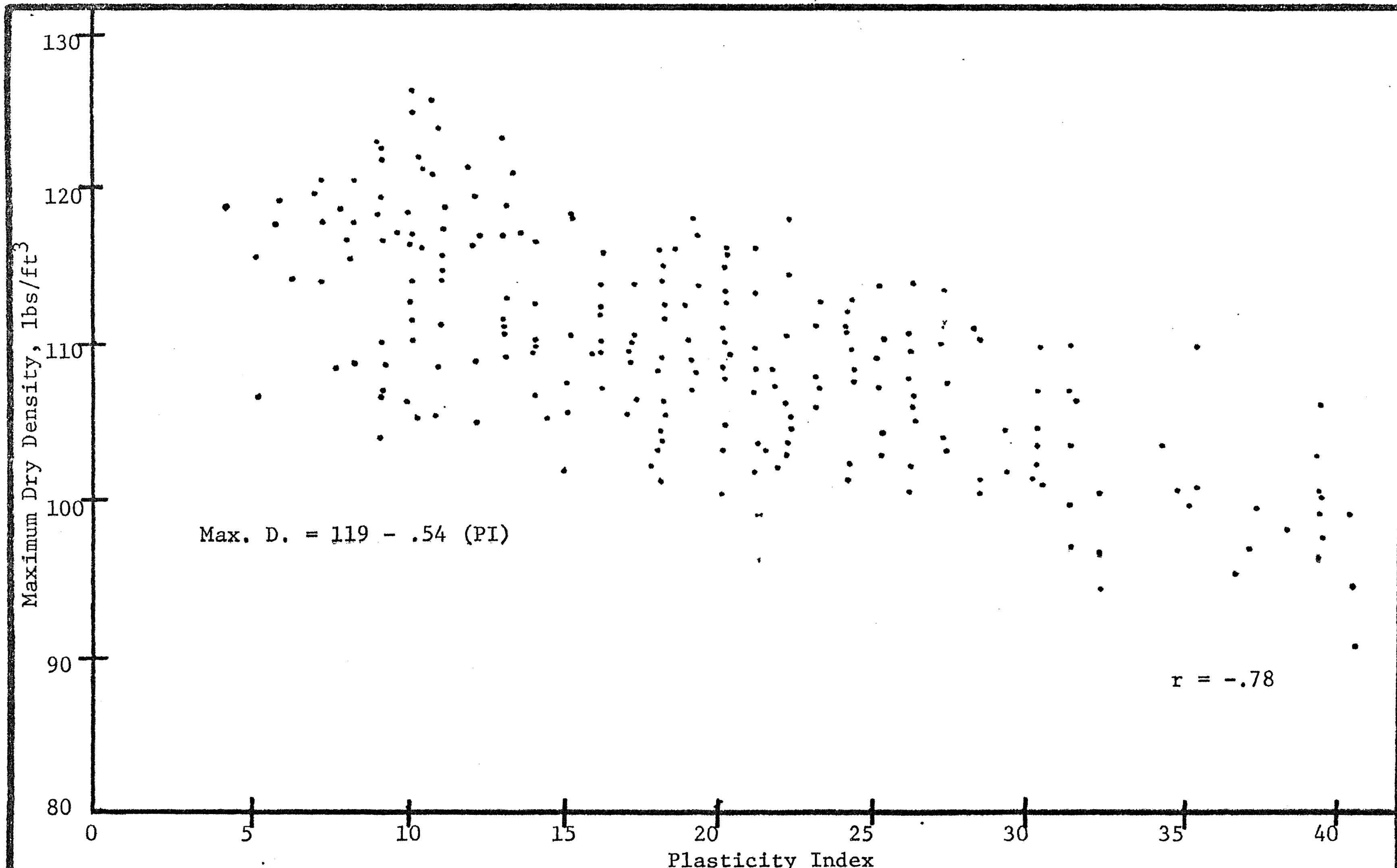


Figure 21. Maximum Dry Density Versus Plasticity Index
(All Soils - Arithmetic Plot)

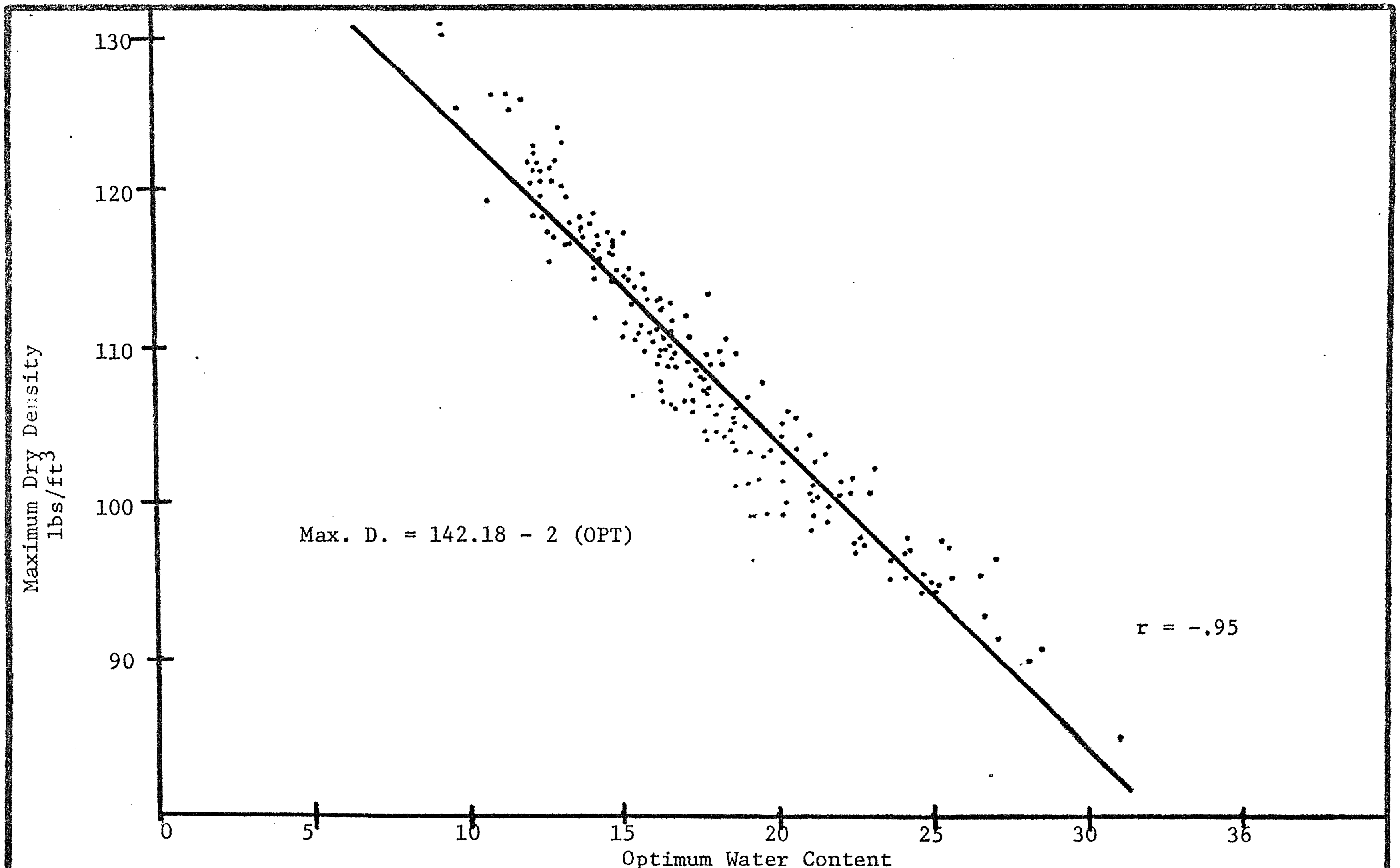


Figure 22. Maximum Dry Density Versus Optimum Moisture Content
(All Soils - Arithmetic Plot)

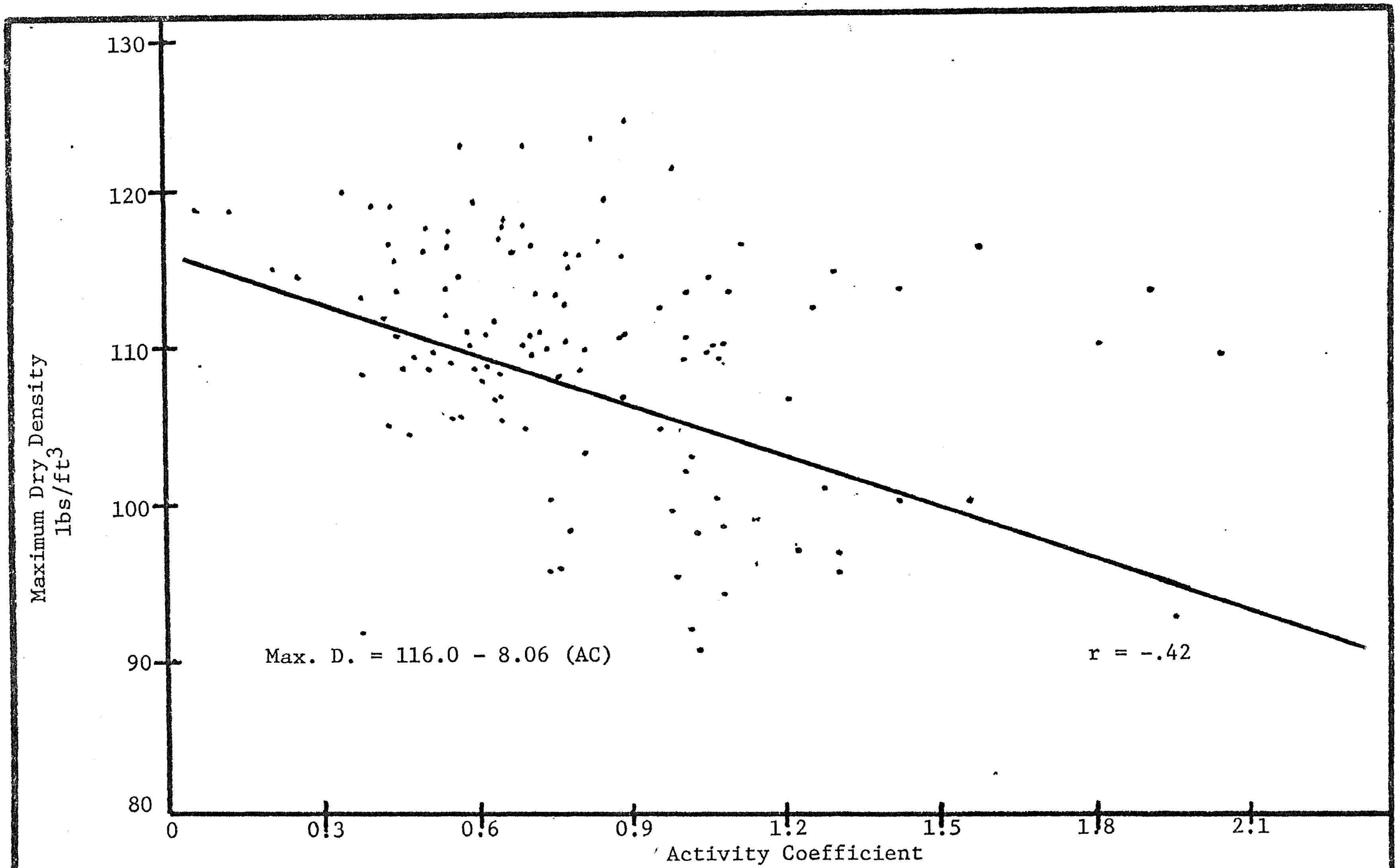


Figure 23. Maximum Dry Density Versus Activity Coefficient (All Soils - Arithmetic Plot

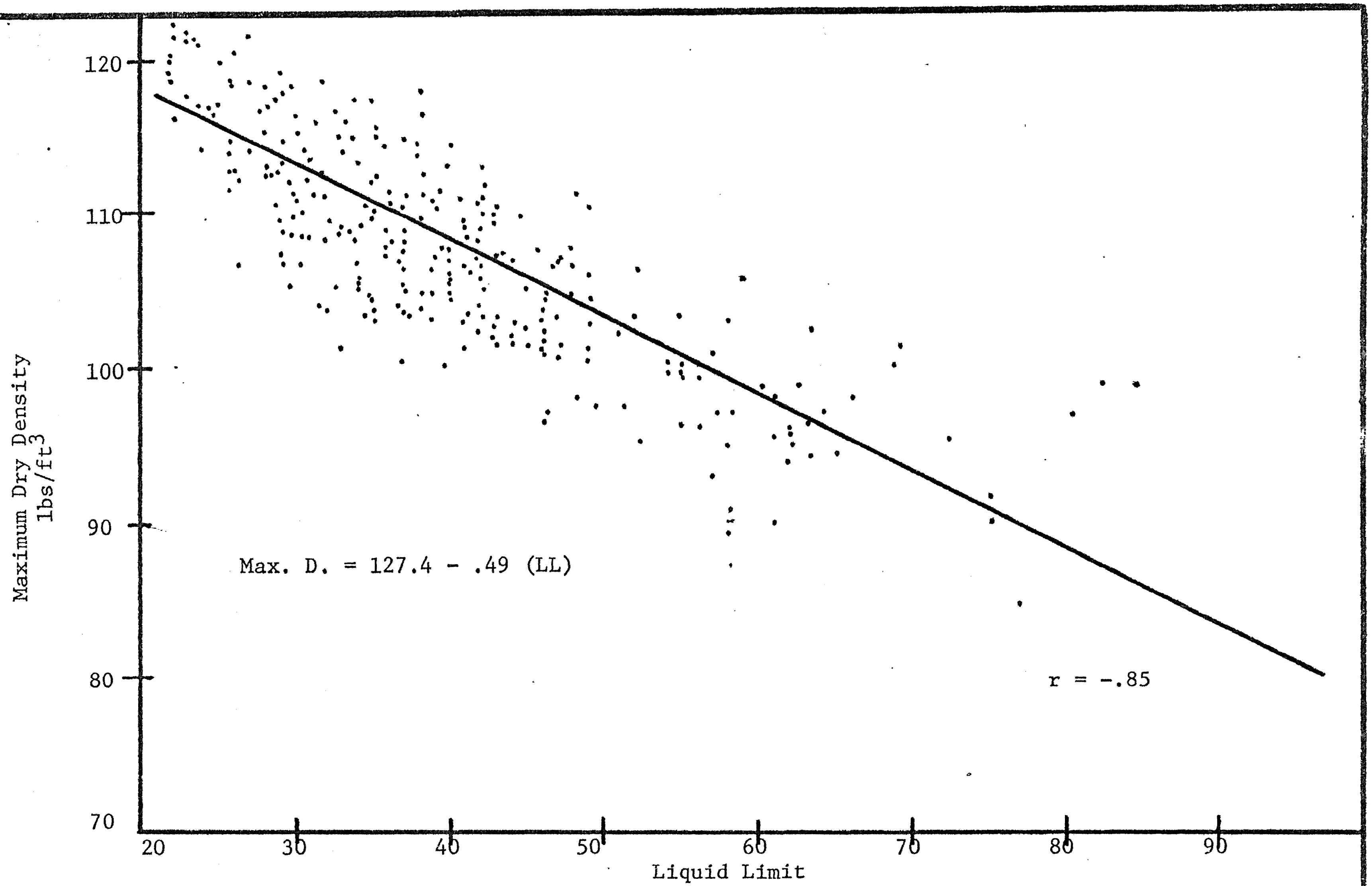


Figure 24. Maximum Dry Density Versus Liquid Limit
(All Soils - Arithmetic Plot)

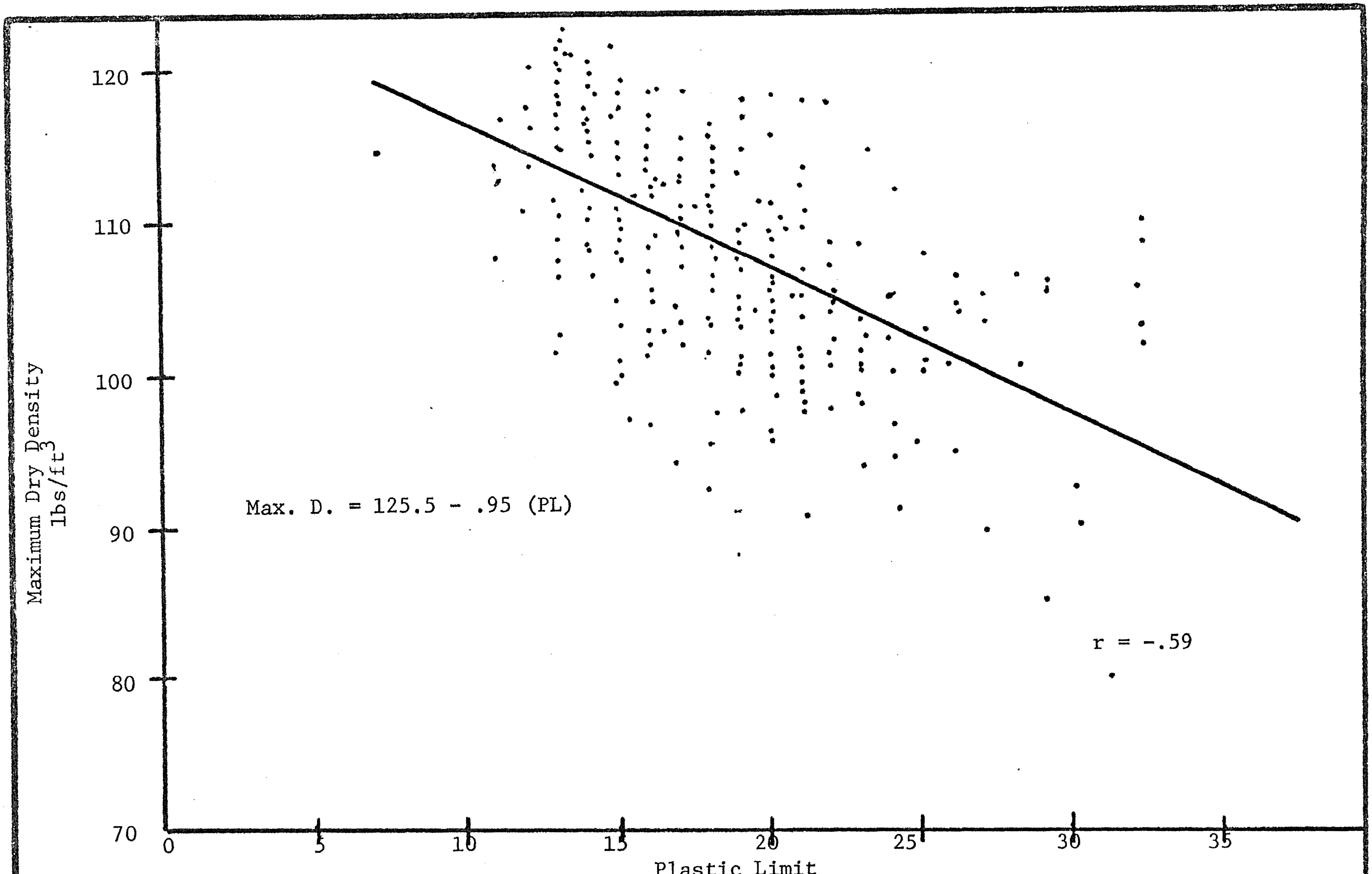


Figure 25. Maximum Dry Density Versus Plastic Limit (All Soils - Arithmetic Plot)

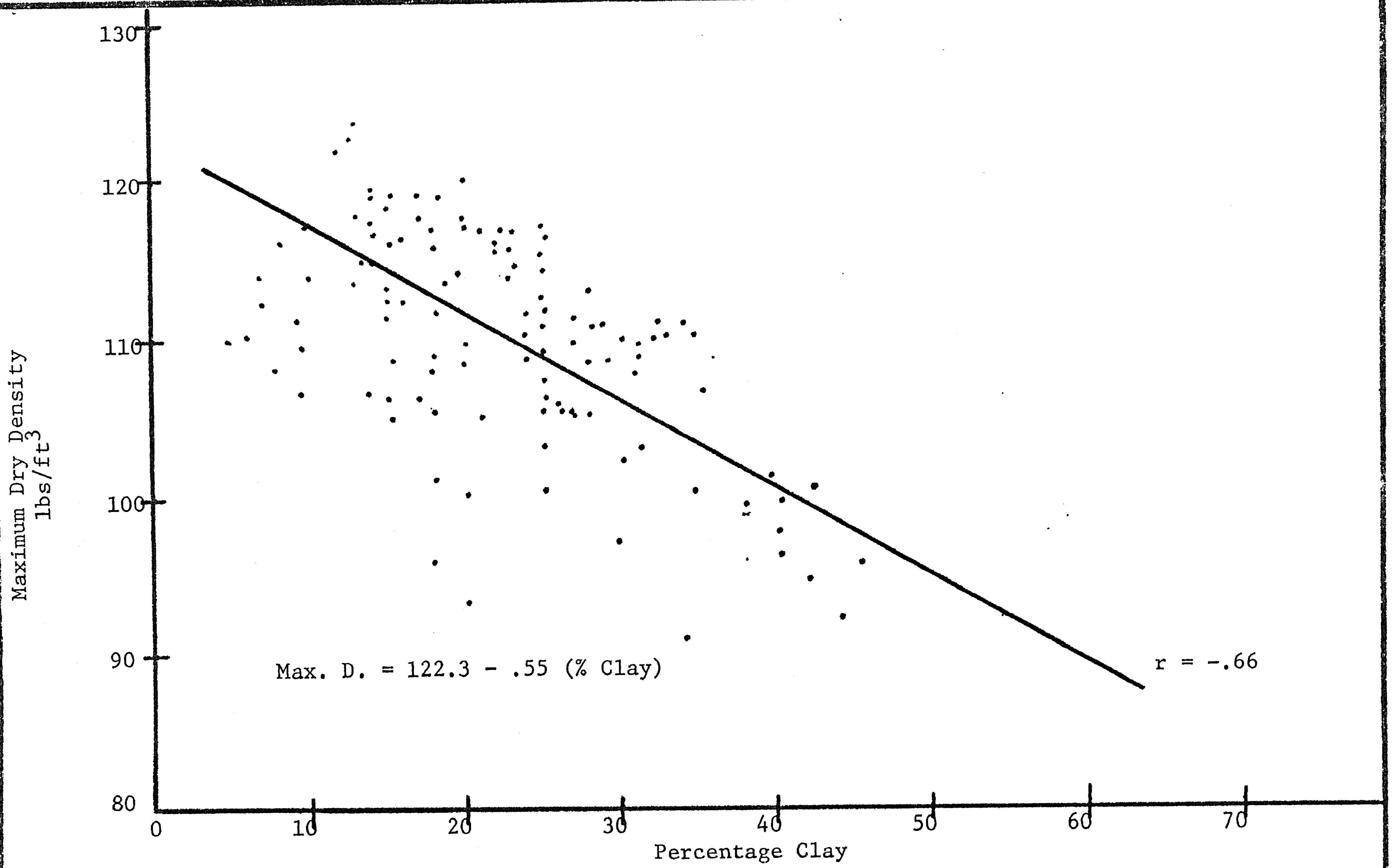


Figure 26. Maximum Dry Density Versus Percentage Clay
(All Soils - Arithmetic Plot)

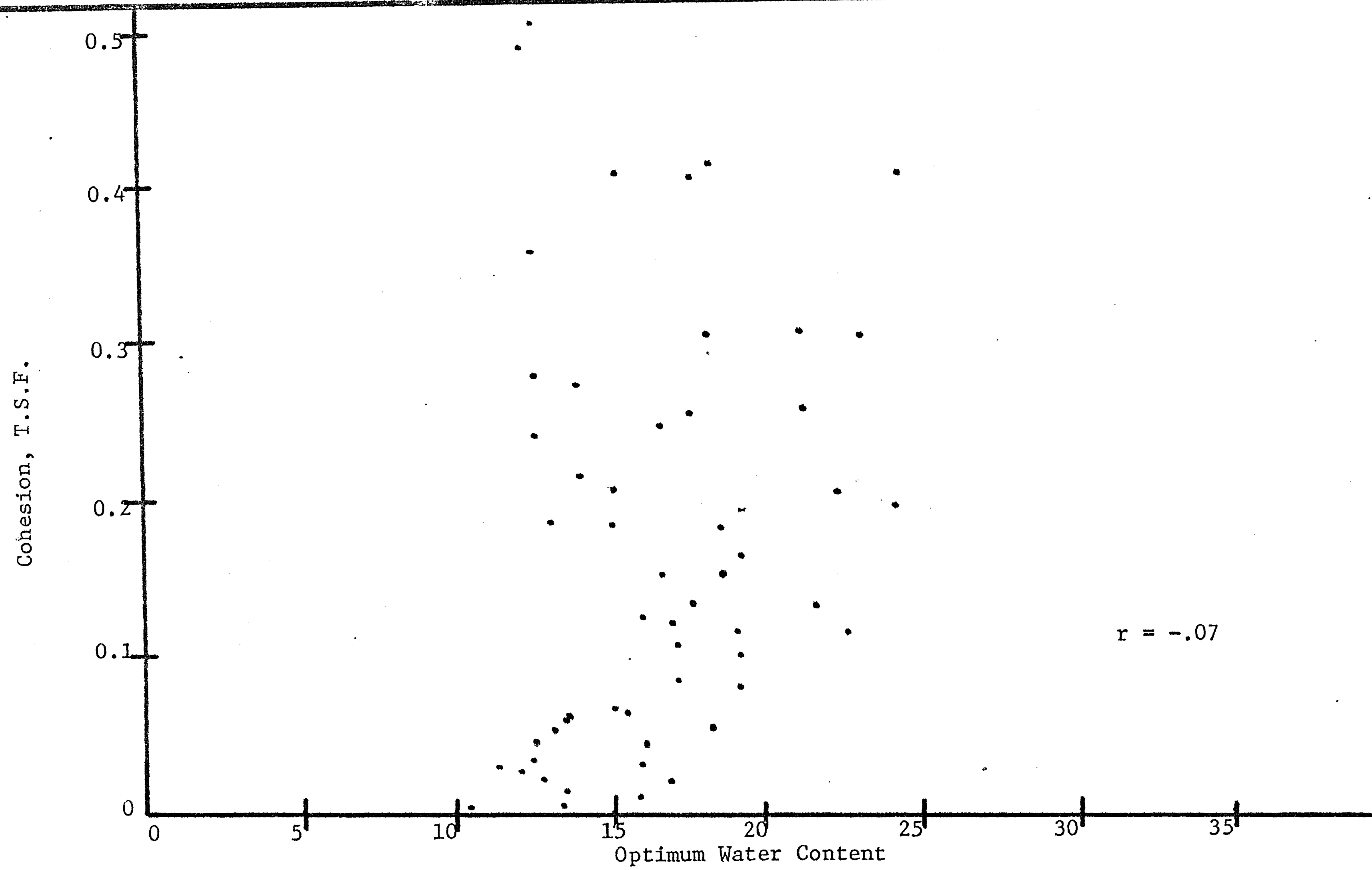


Figure 27. Cohesion Versus Optimum Water Content
(All Soils - Arithmetic Plot)

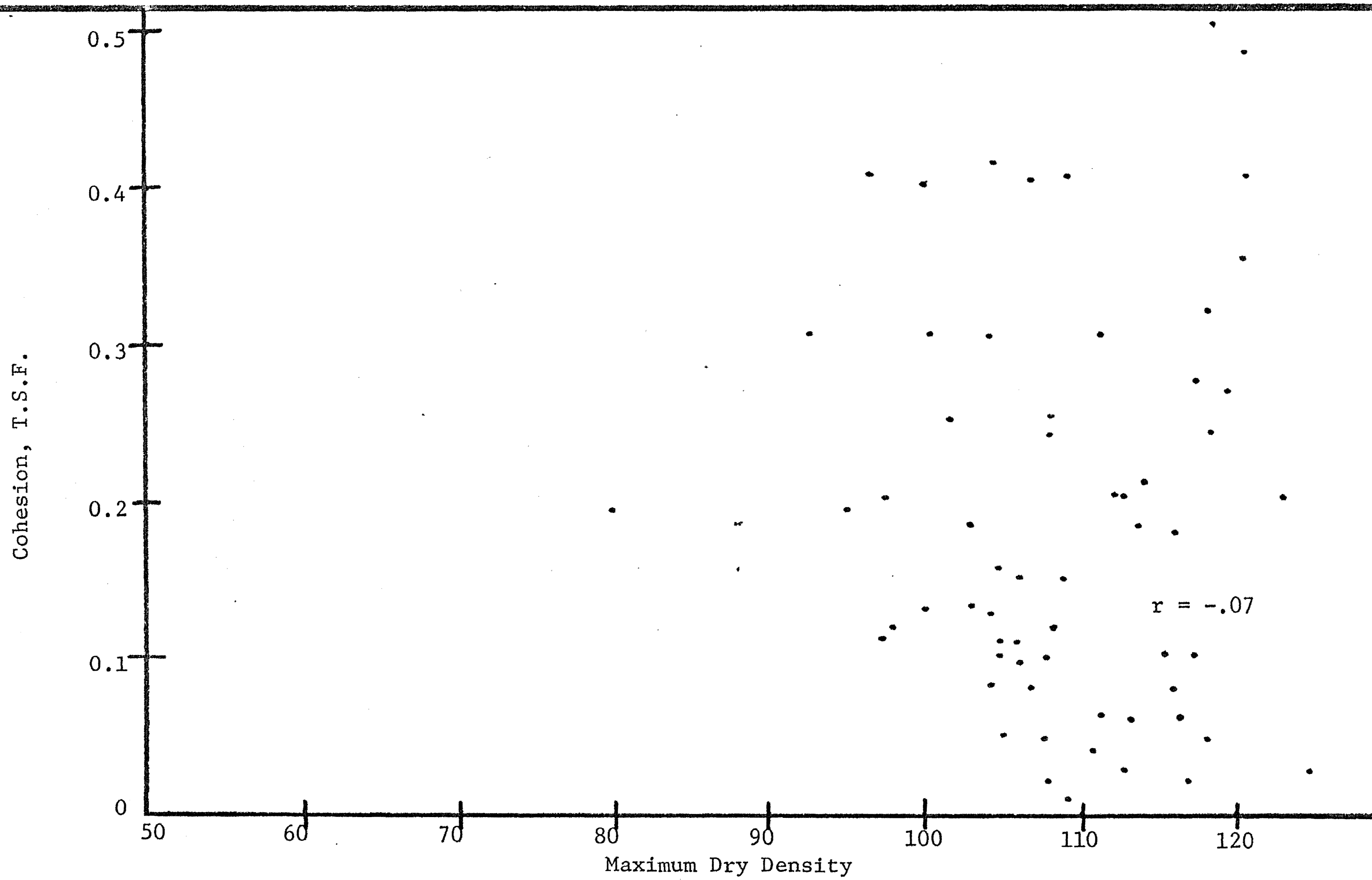


Figure 28. Cohesion Versus Maximum Dry Density
(All Soils - Arithmetic Plot)

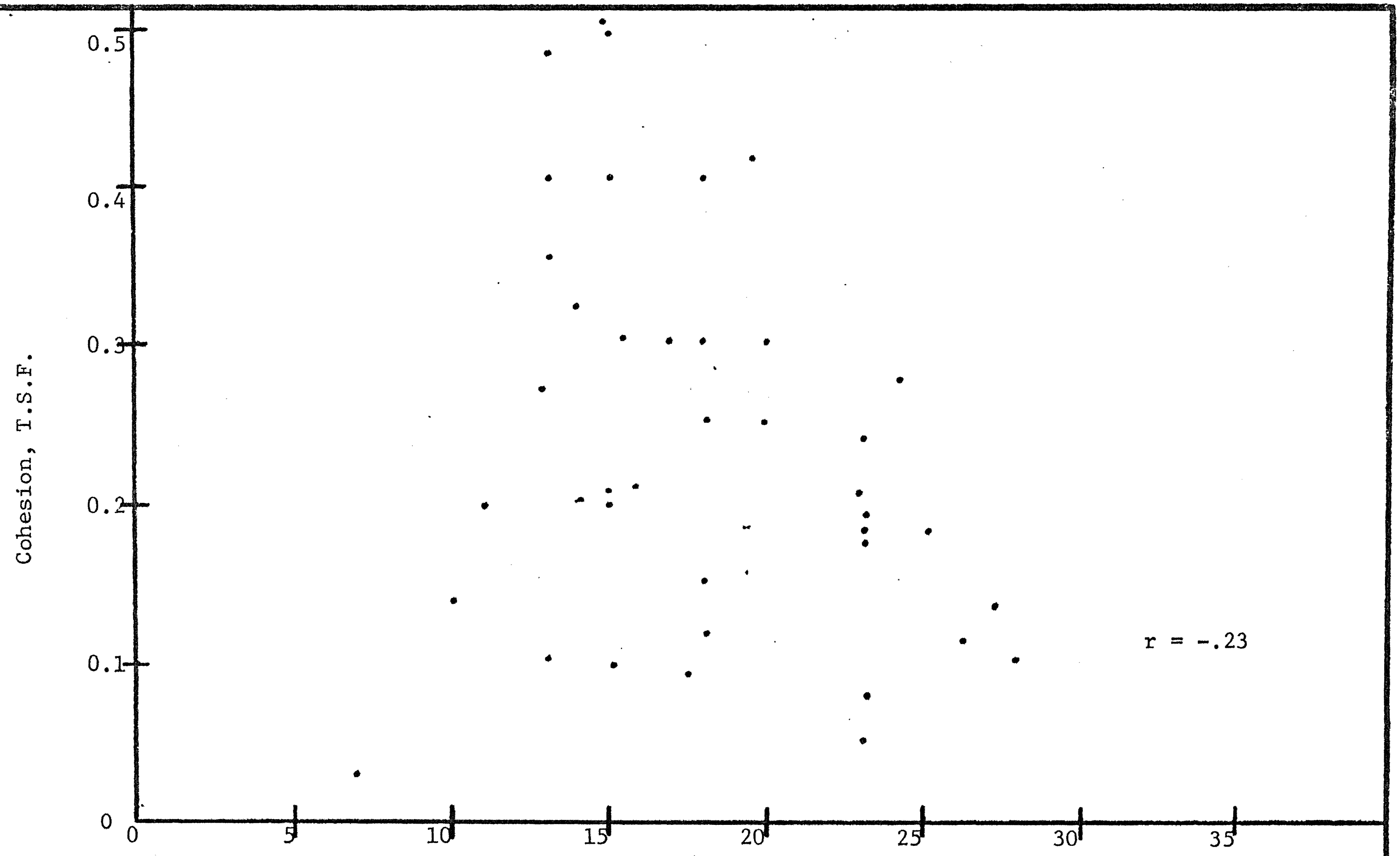


Figure 29. Cohesion Versus Plastic Limit
(All Soils - Arithmetic Plot)

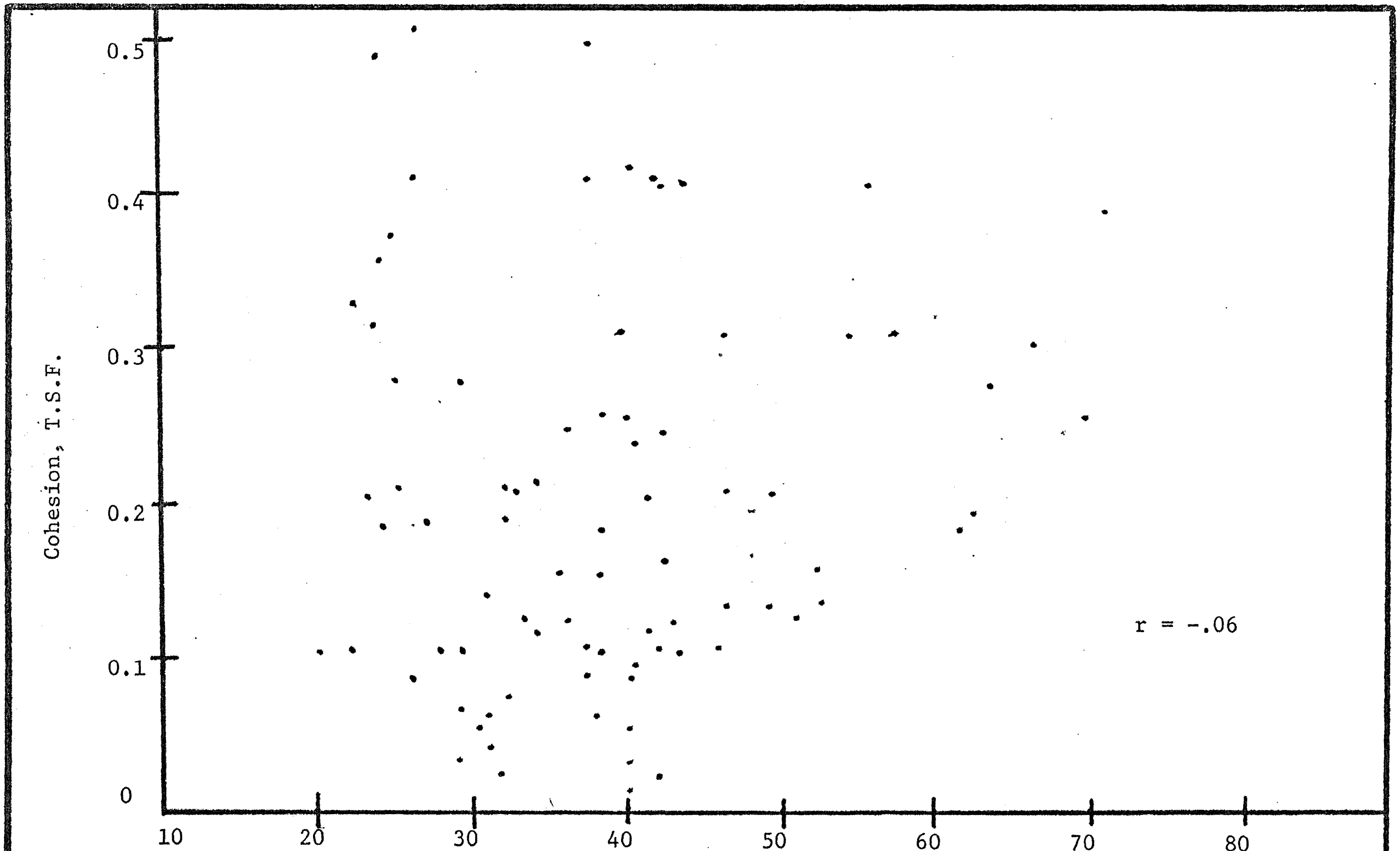


Figure 30. Cohesion Versus Liquid Limit (All Soils - Arithmetic Plot)

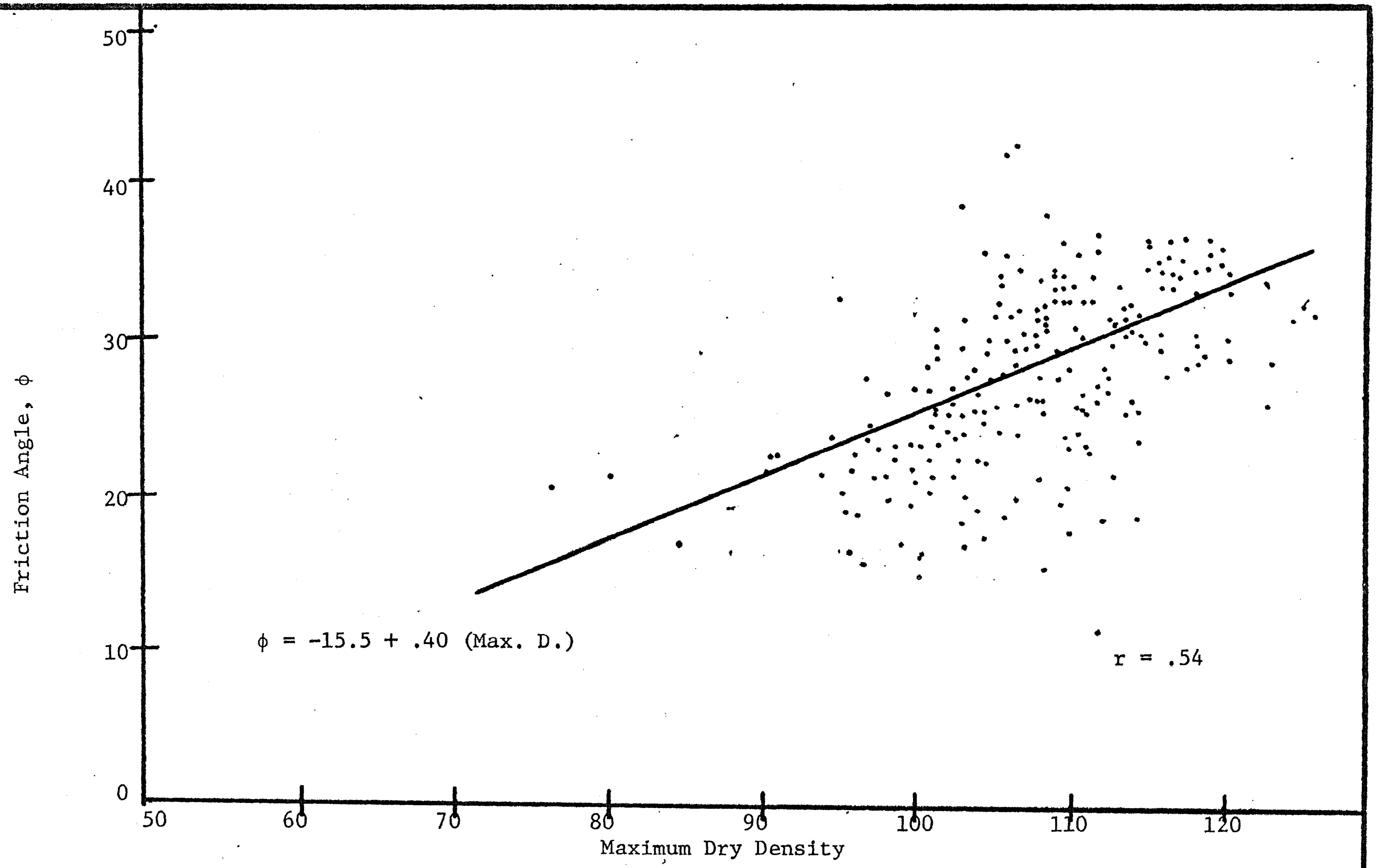


Figure 31. Friction Angle ϕ Versus Maximum Dry Density
(All Soils - Arithmetic Plot)

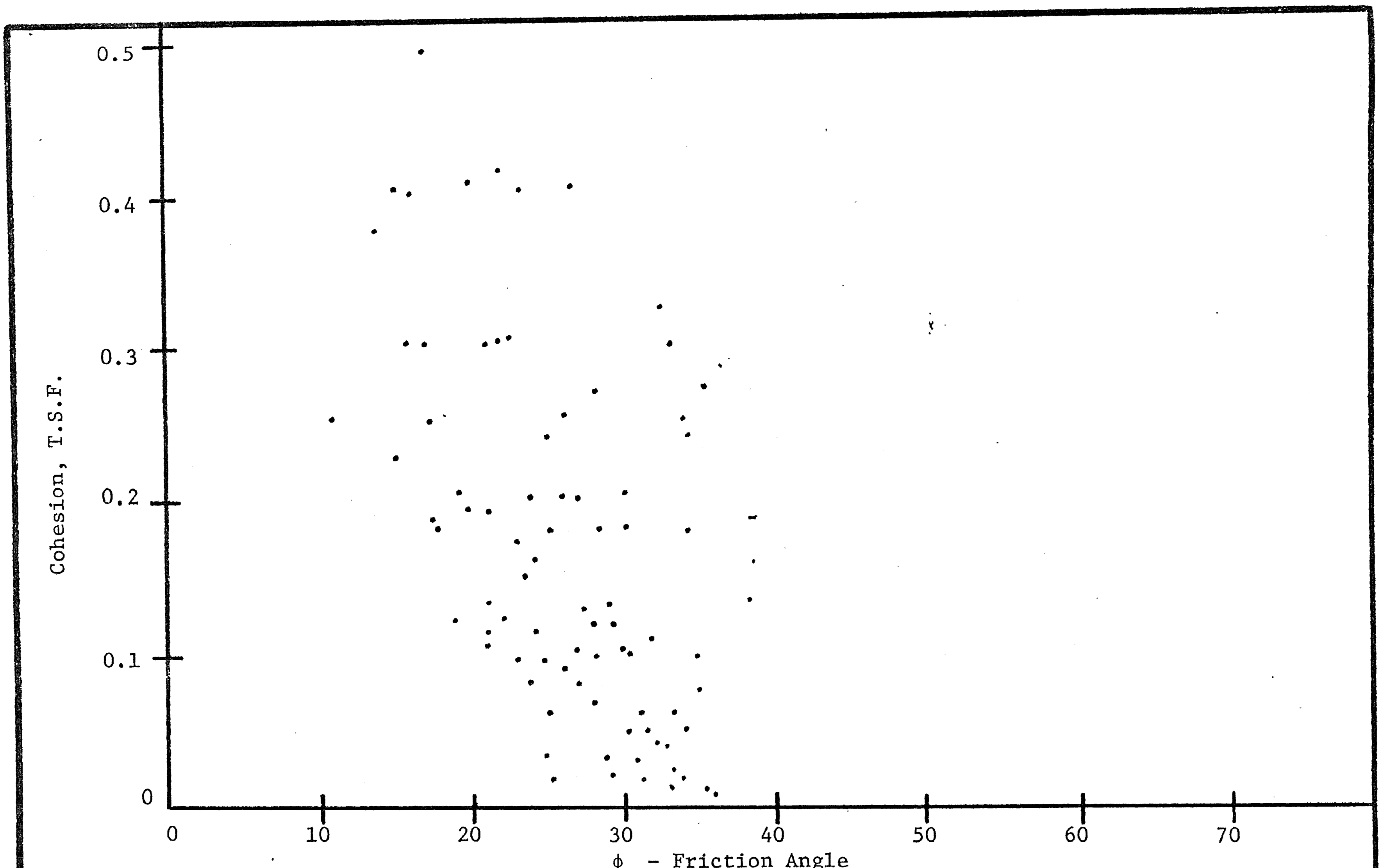


Figure 32. Cohesion Versus Friction Angle

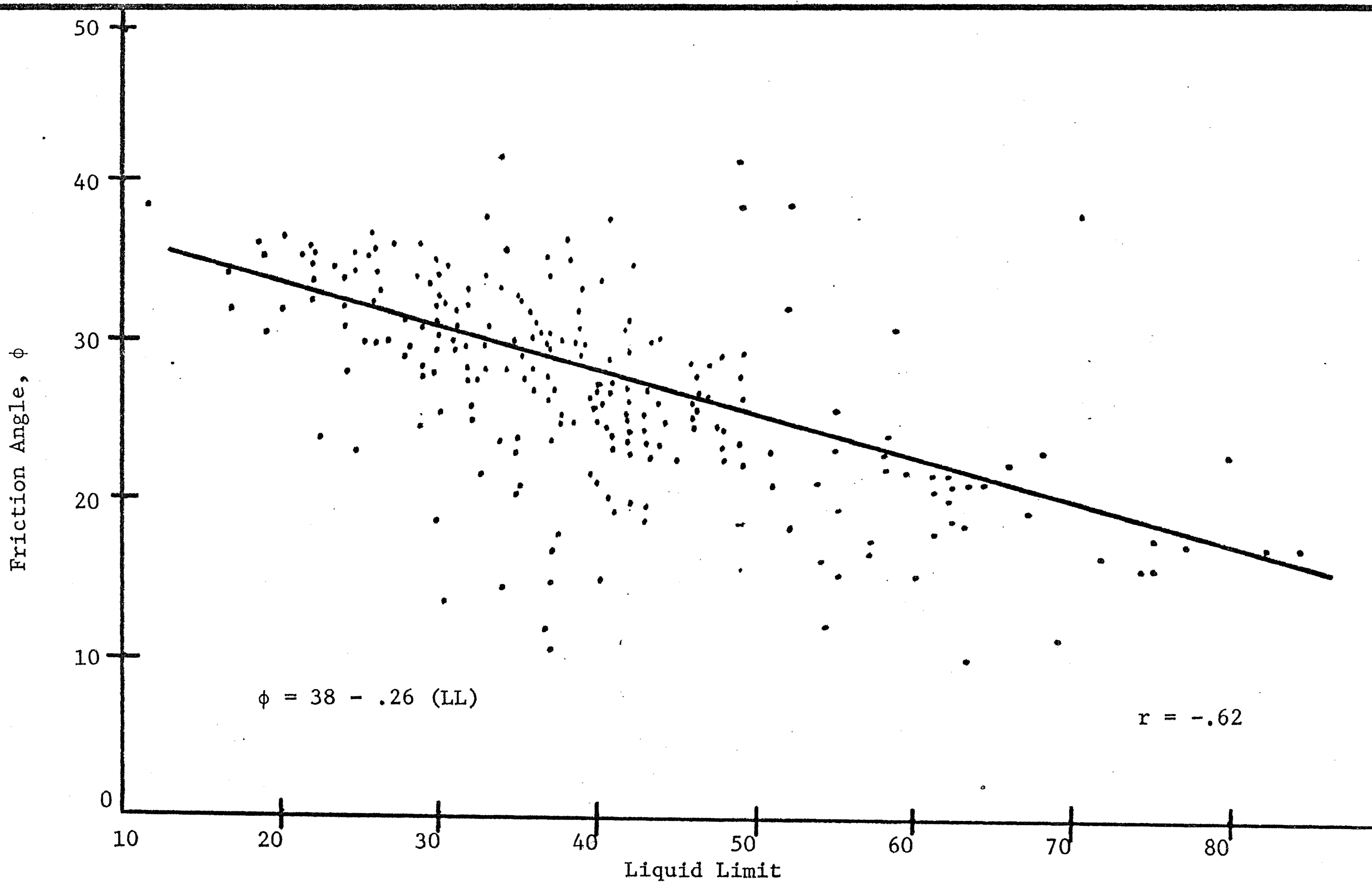


Figure 33. Friction Angle ϕ Versus Liquid Limit

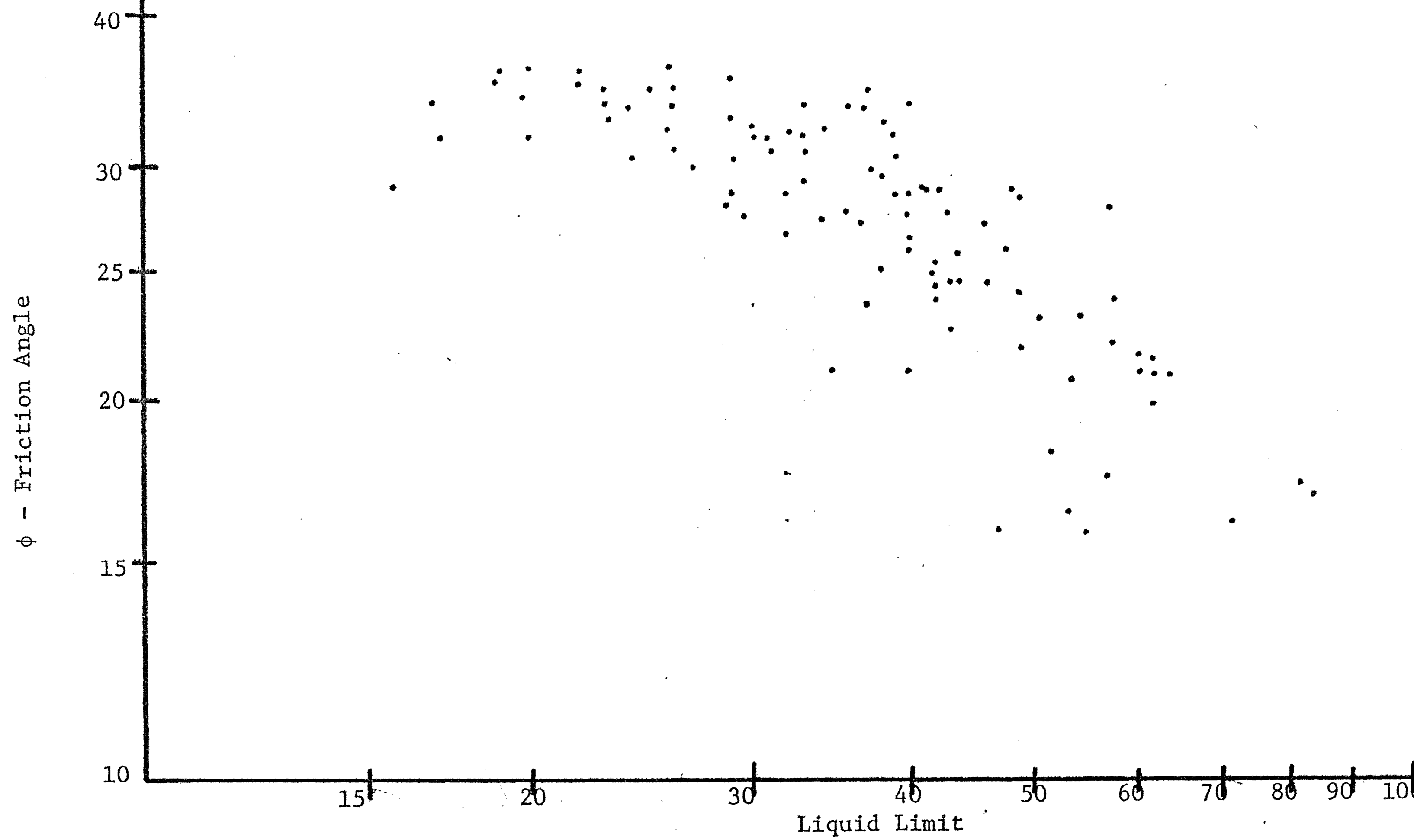


Figure 34. Friction Angle Versus Liquid Limit
(All Soils - Logarithmic Plot)

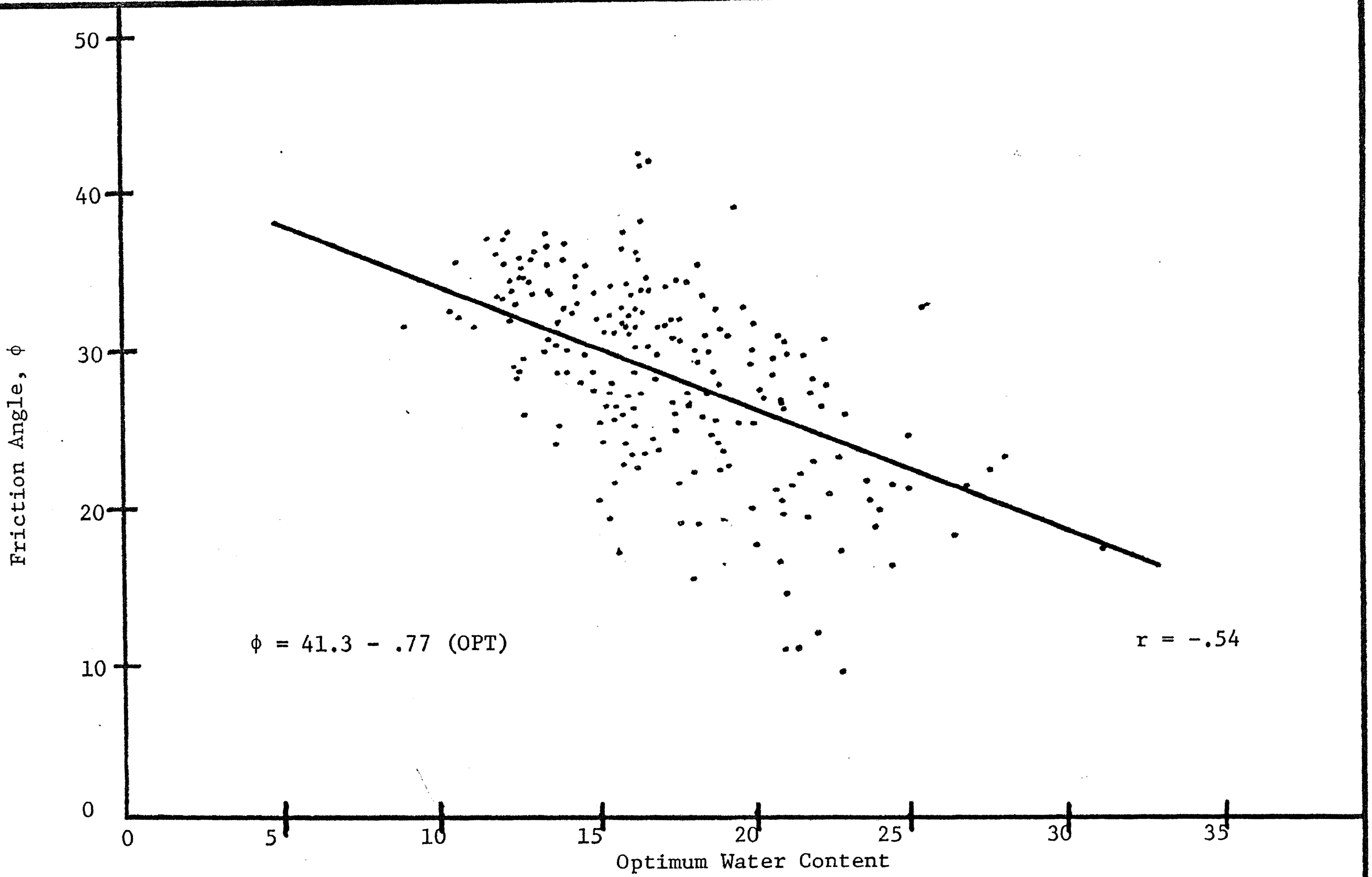


Figure 35. Friction Angle φ Versus Optimum Moisture Content (All Soils - Arithmetic Plot)

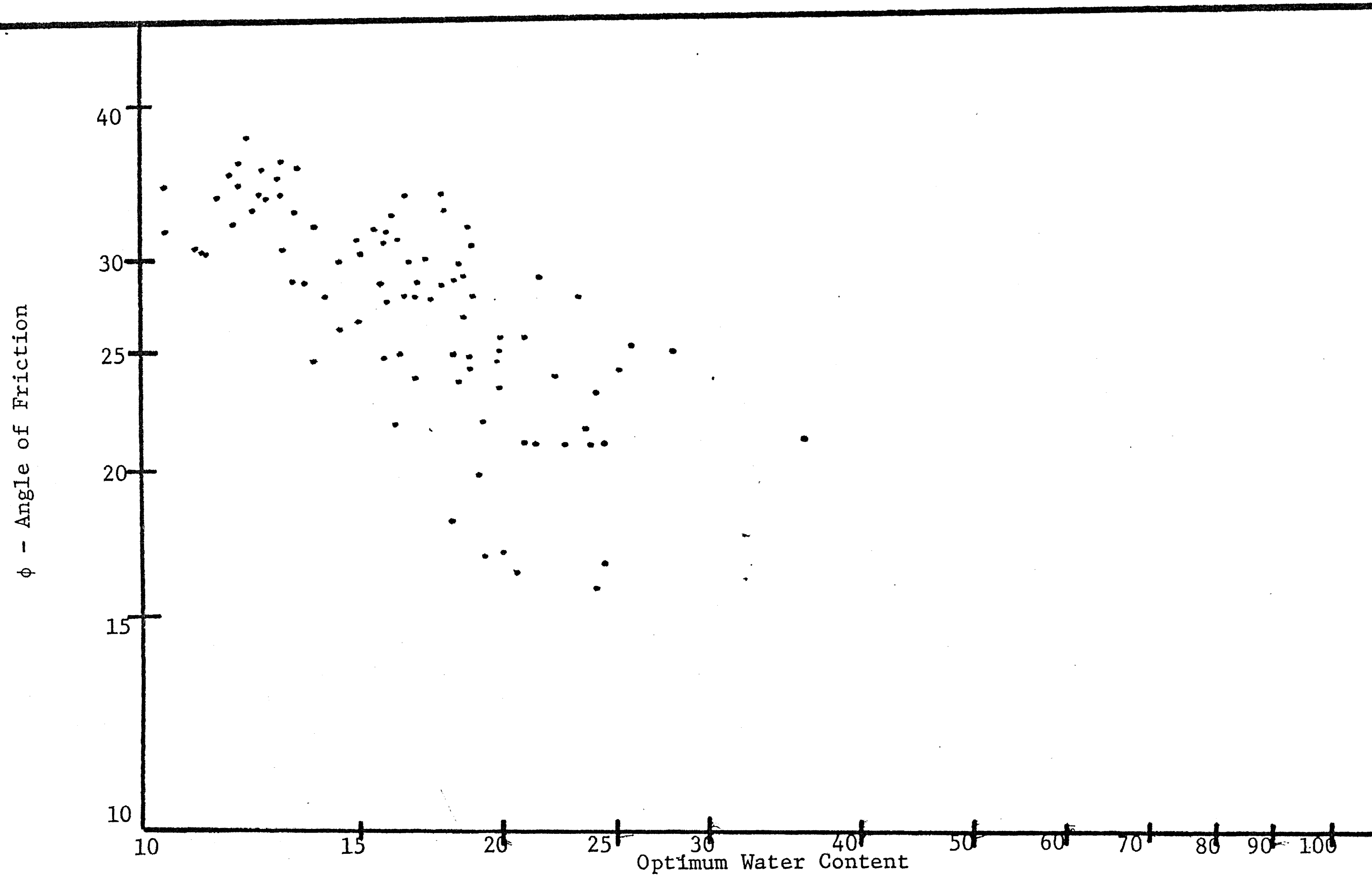


Figure 36. Friction Angle Versus Optimum Moisture Content
(All Soils - Logarithmic Plot)

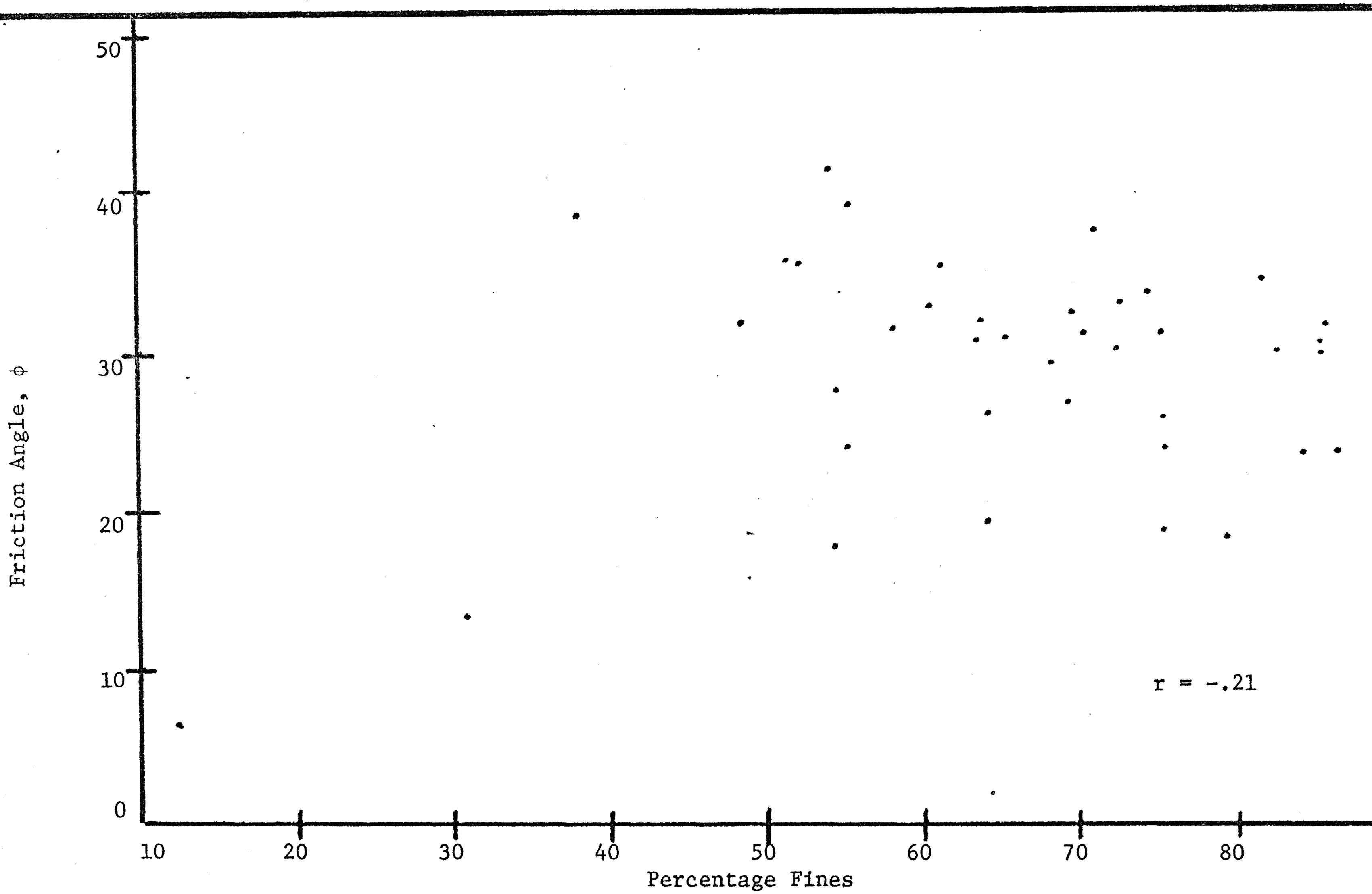


Figure 37. Friction Angle ϕ Versus Percent Fines
(All Soils - Arithmetic Plot)

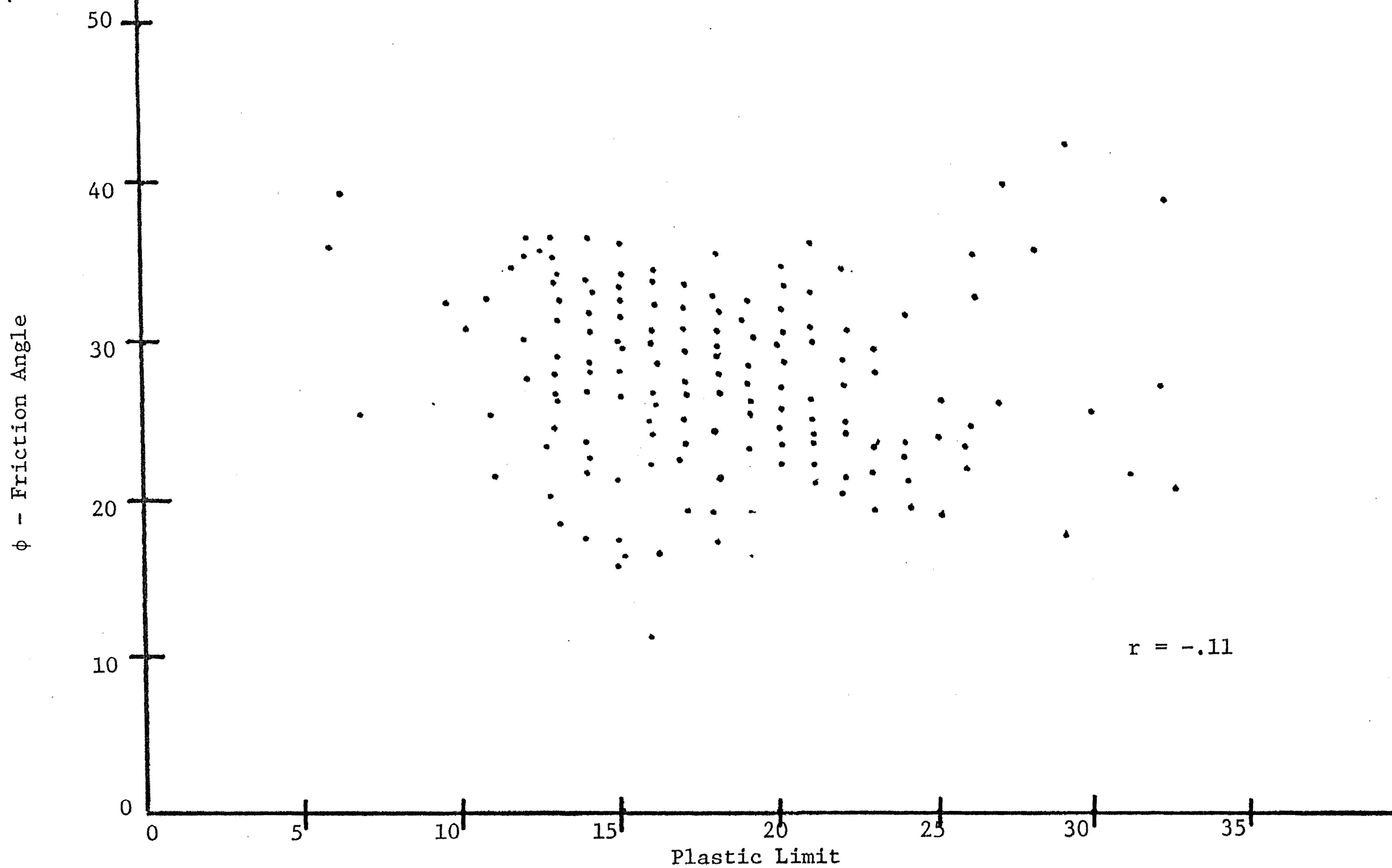


Figure 38. ϕ - Friction Angle Versus Plastic Limit
(All Soils Arithmetic Plot)

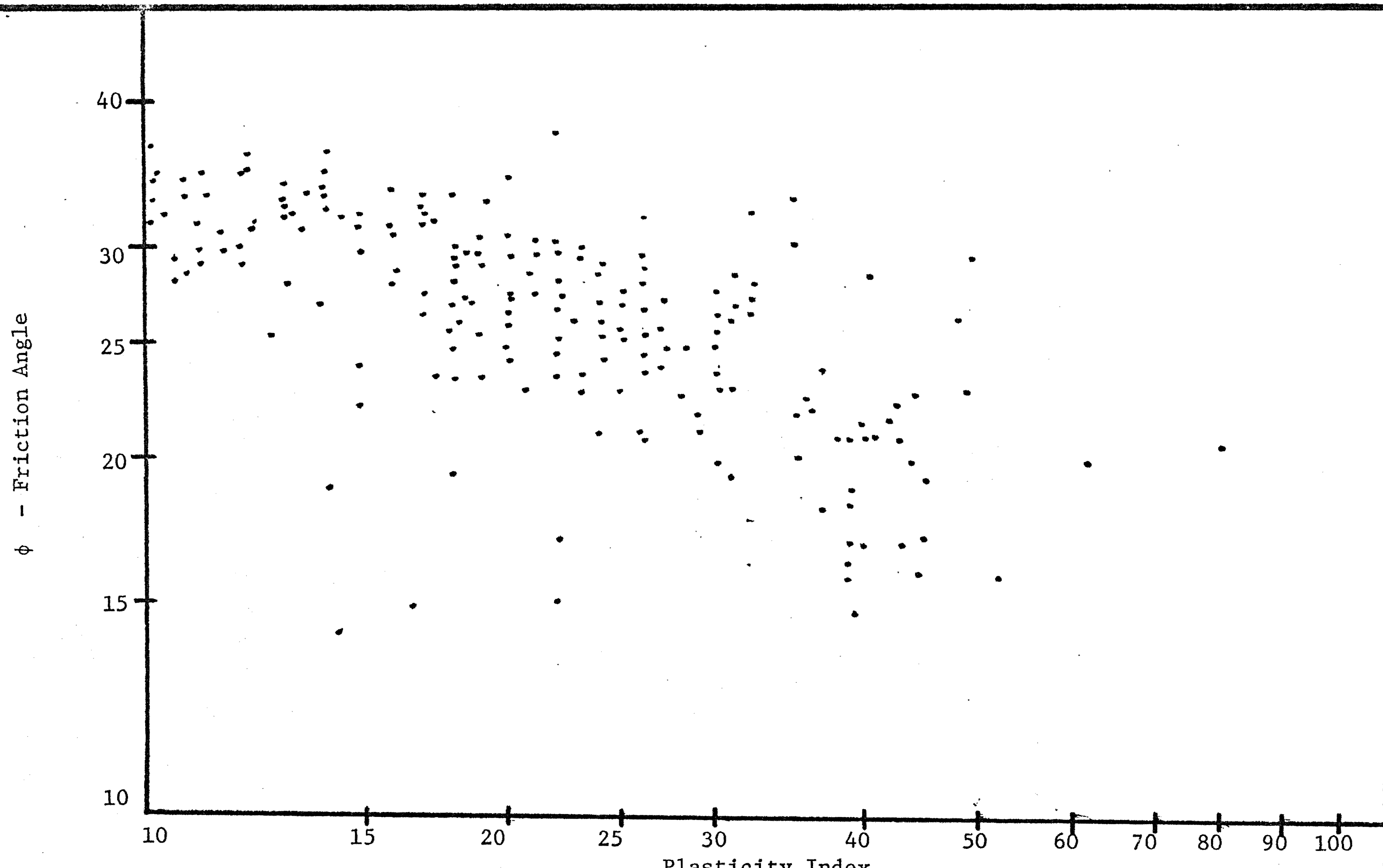


Figure 39. Friction Angle Versus Plasticity Index
(All Soils - Arithmetic Plot)

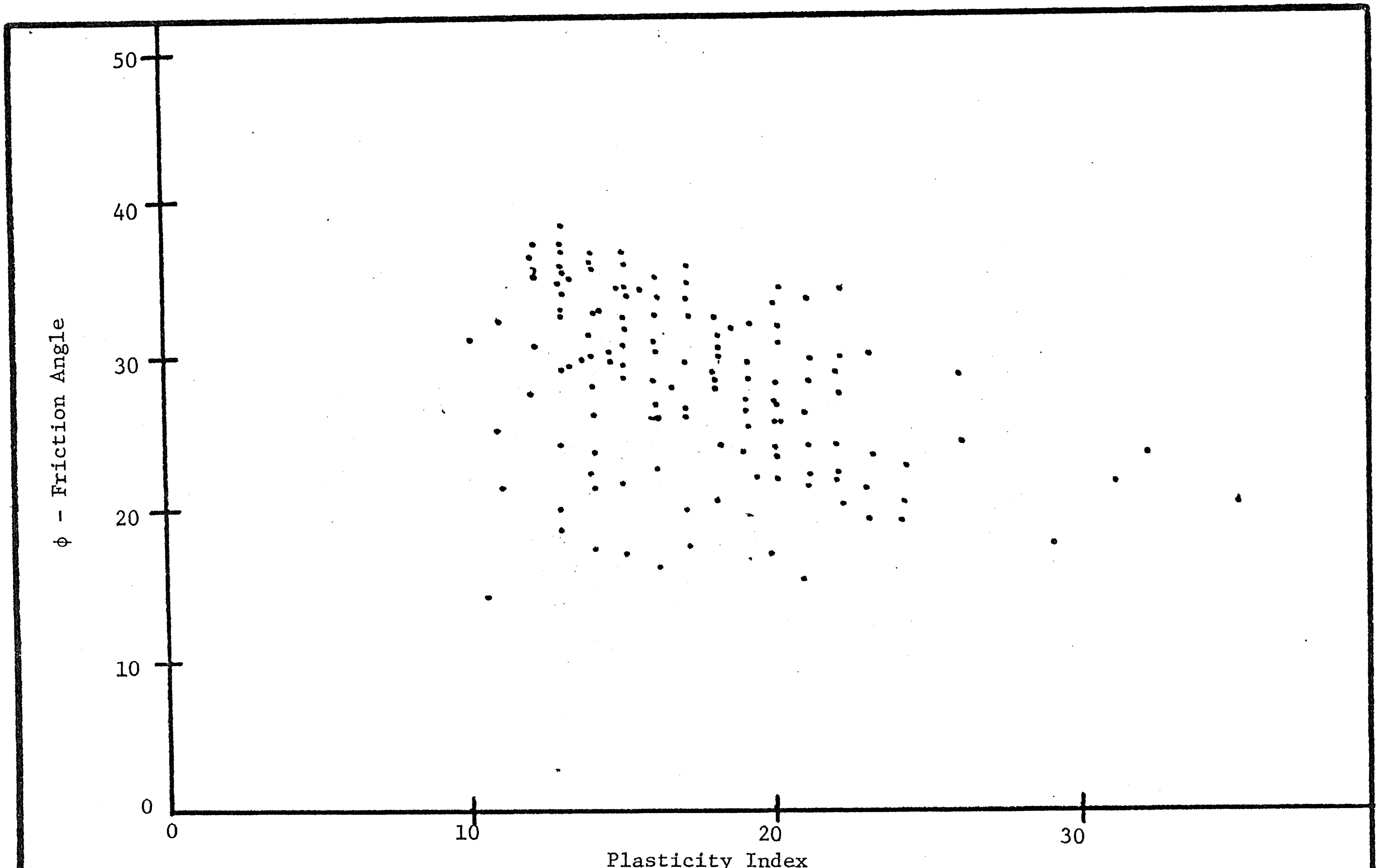


Figure 40. Friction Angle Versus Plasticity Index
(All Soils - Logarithmic Plot)

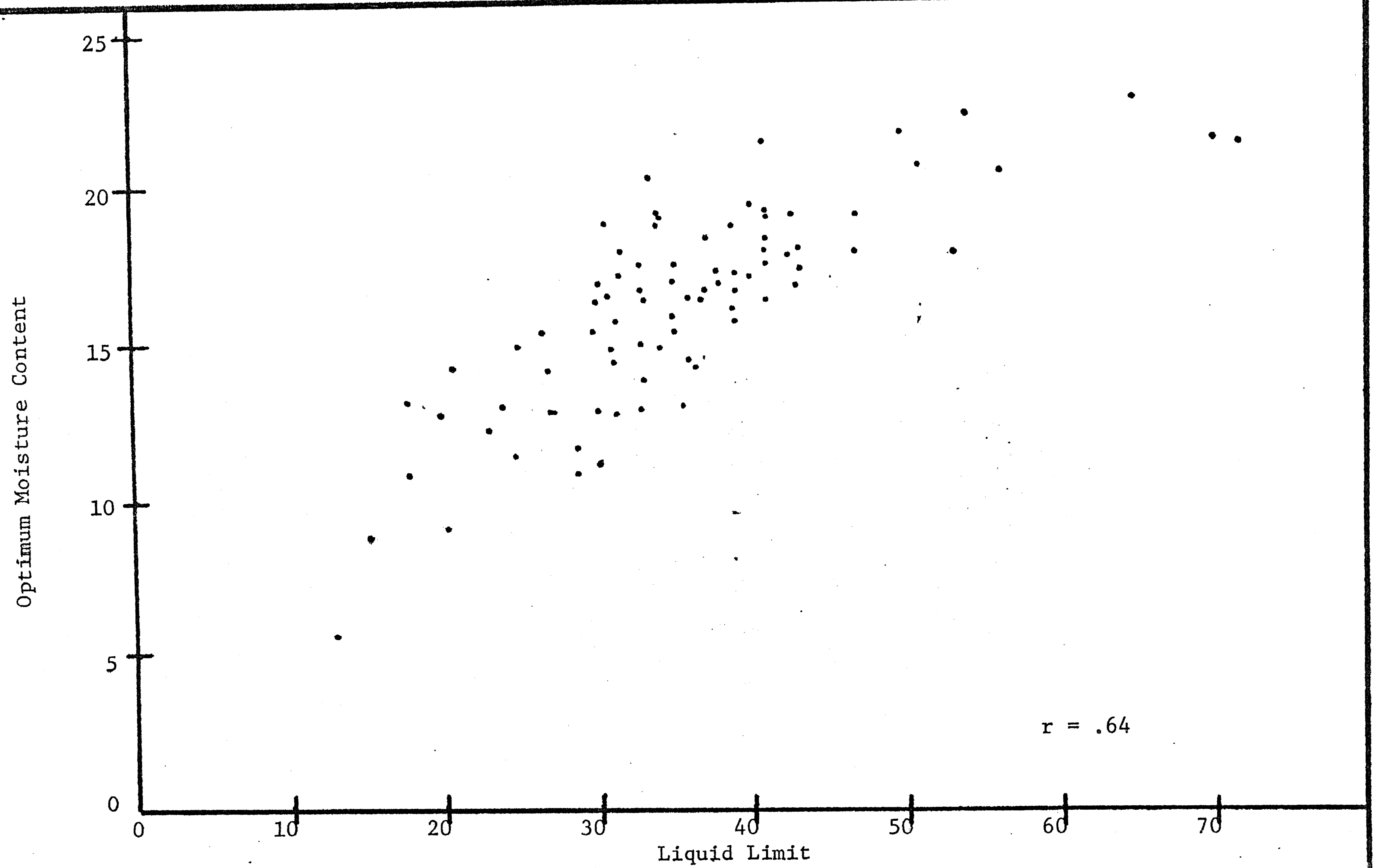


Figure 41. Optimum Moisture Content Versus Liquid Limit
(Glacial Soils - Arithmetic Plot)

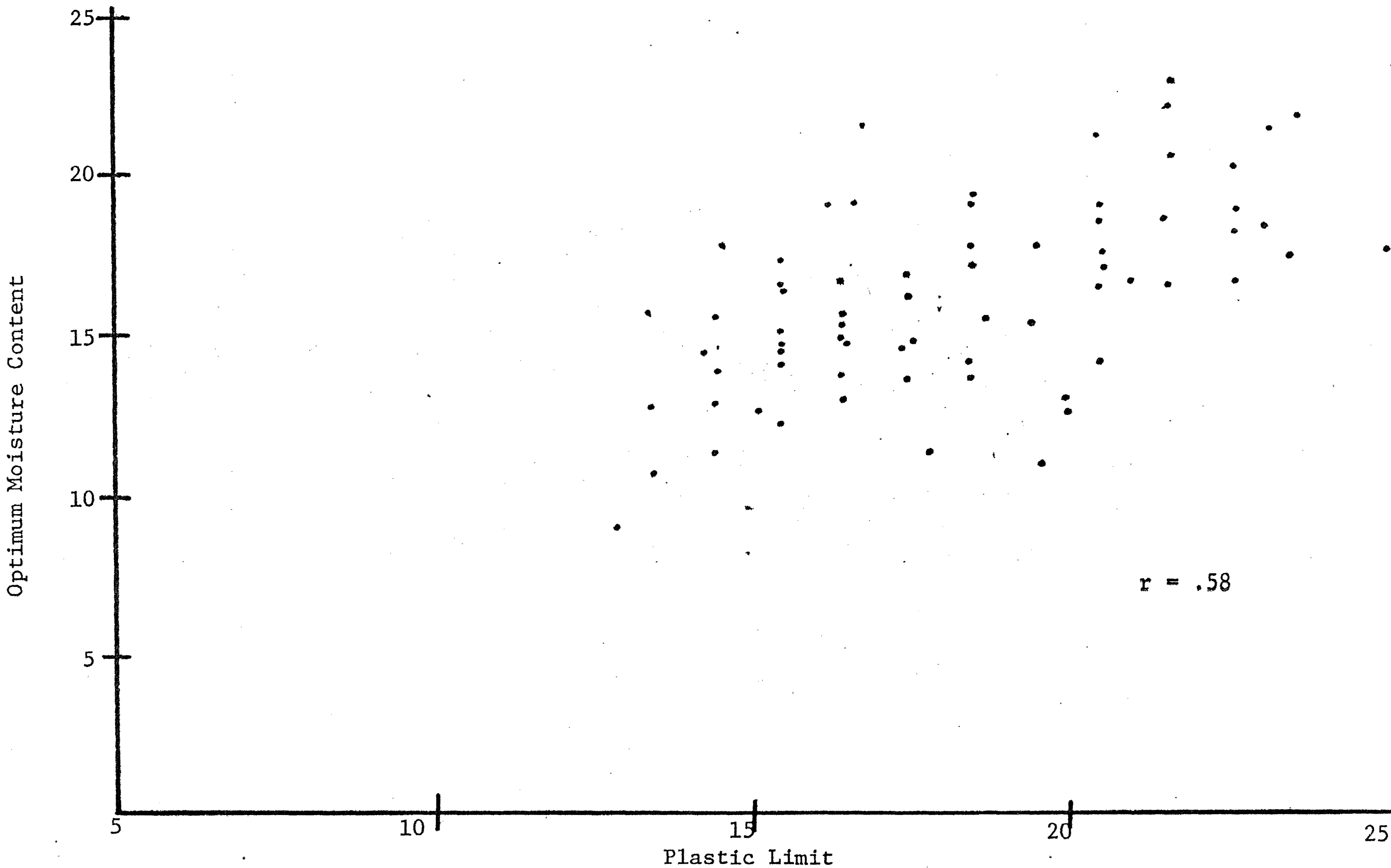


Figure 42. Optimum Moisture Content Versus Plastic Limit
(Glacial Soils - Arithmetic Plot)

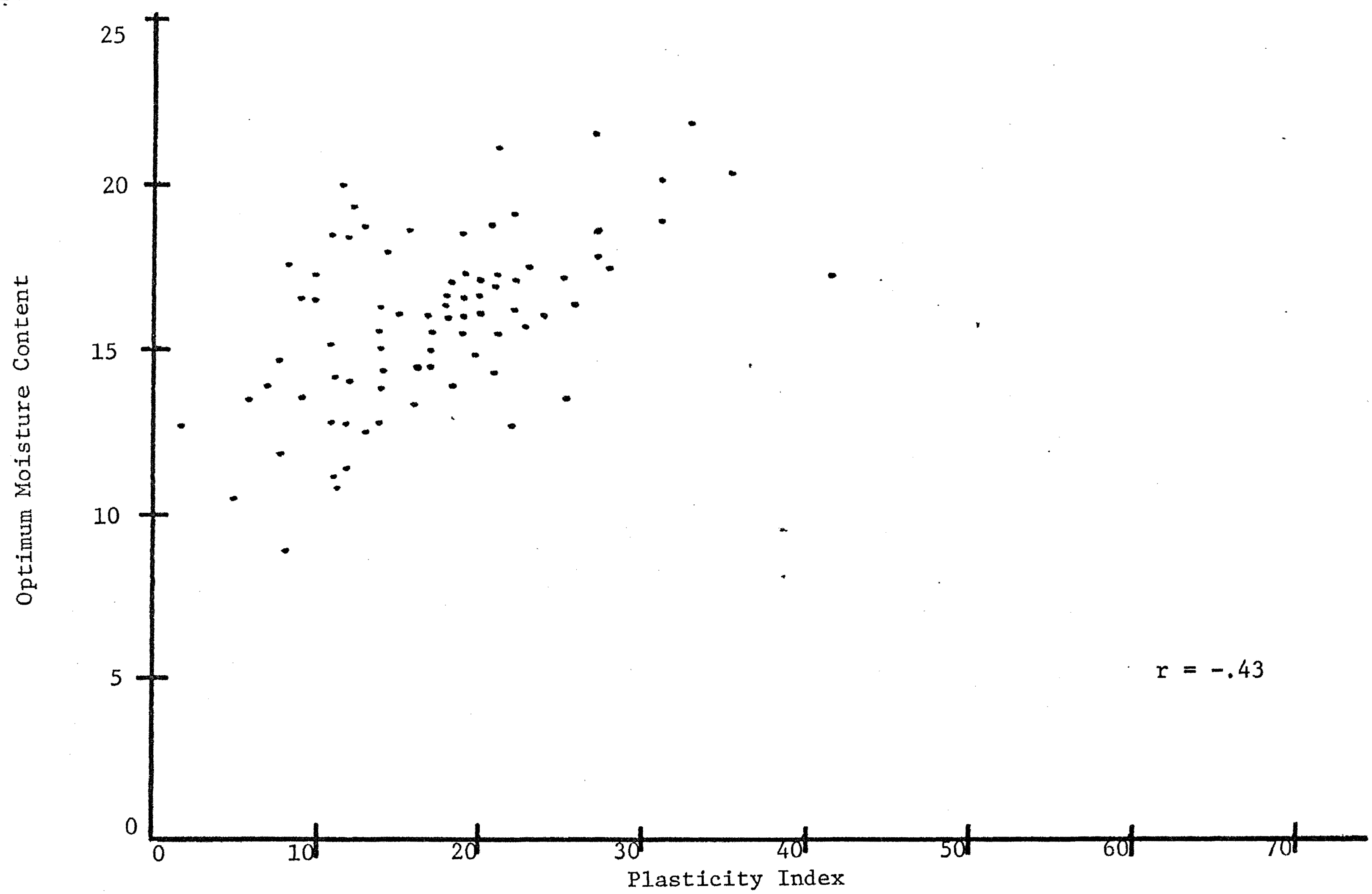


Figure 43. Optimum Moisture Content Versus Plasticity Index
(Glacial Soils - Arithmetic Plot)

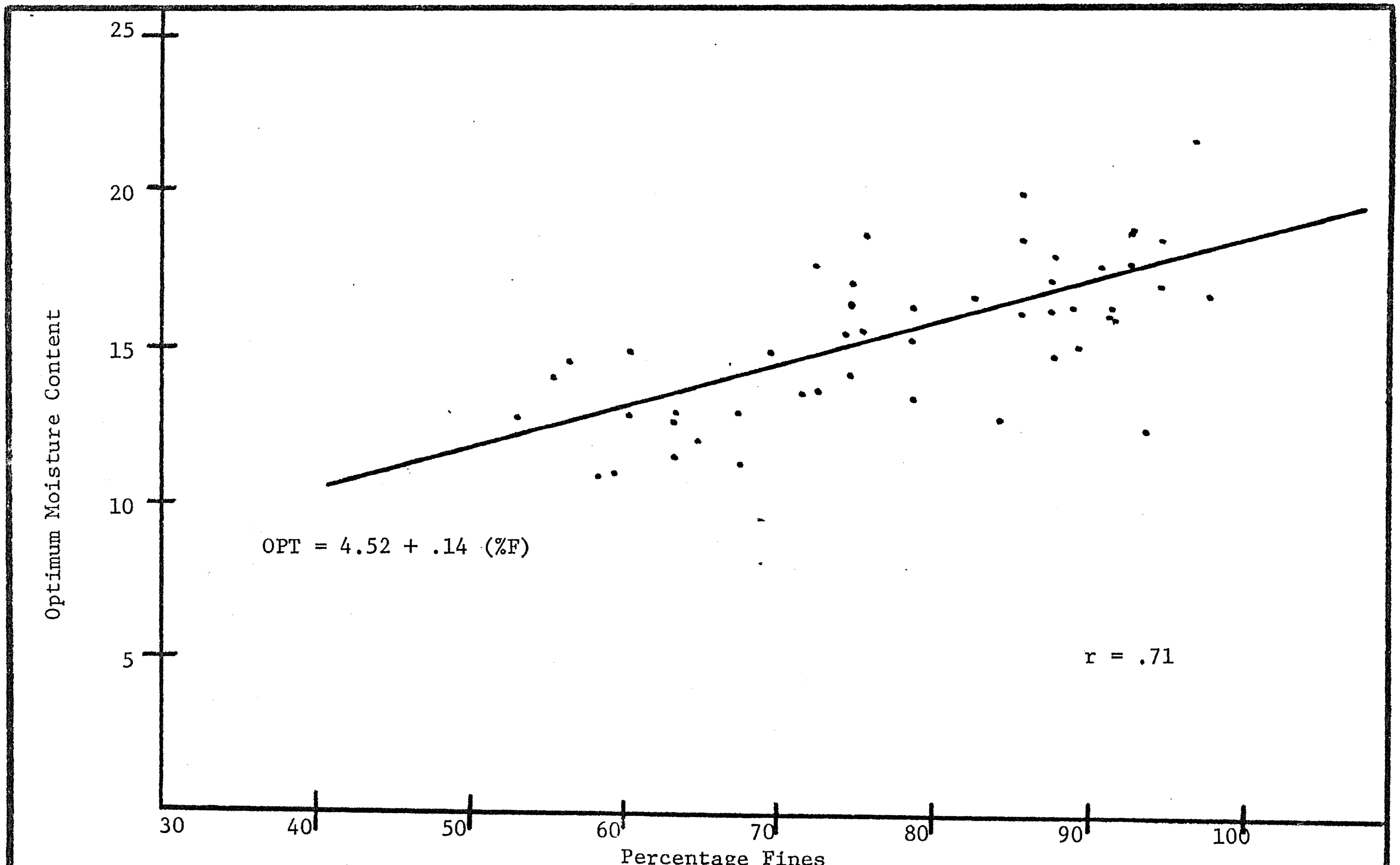


Figure 44. Optimum Moisture Content Versus Percent Fines
(Glacial Soils - Arithmetic Plot)

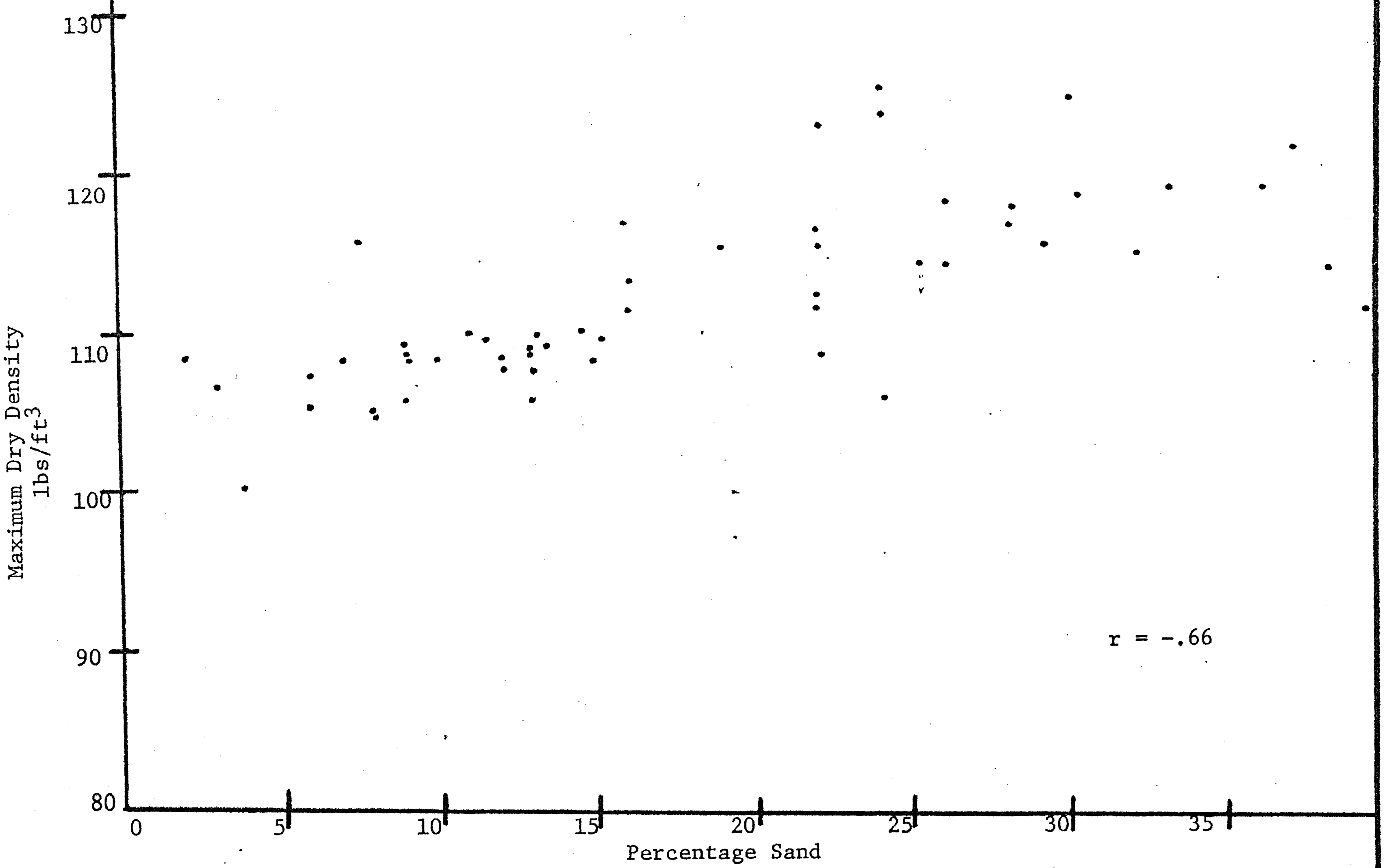


Figure 45. Maximum Dry Density Versus Percent Sand
(Glacial Soils - Arithmetic Plot)

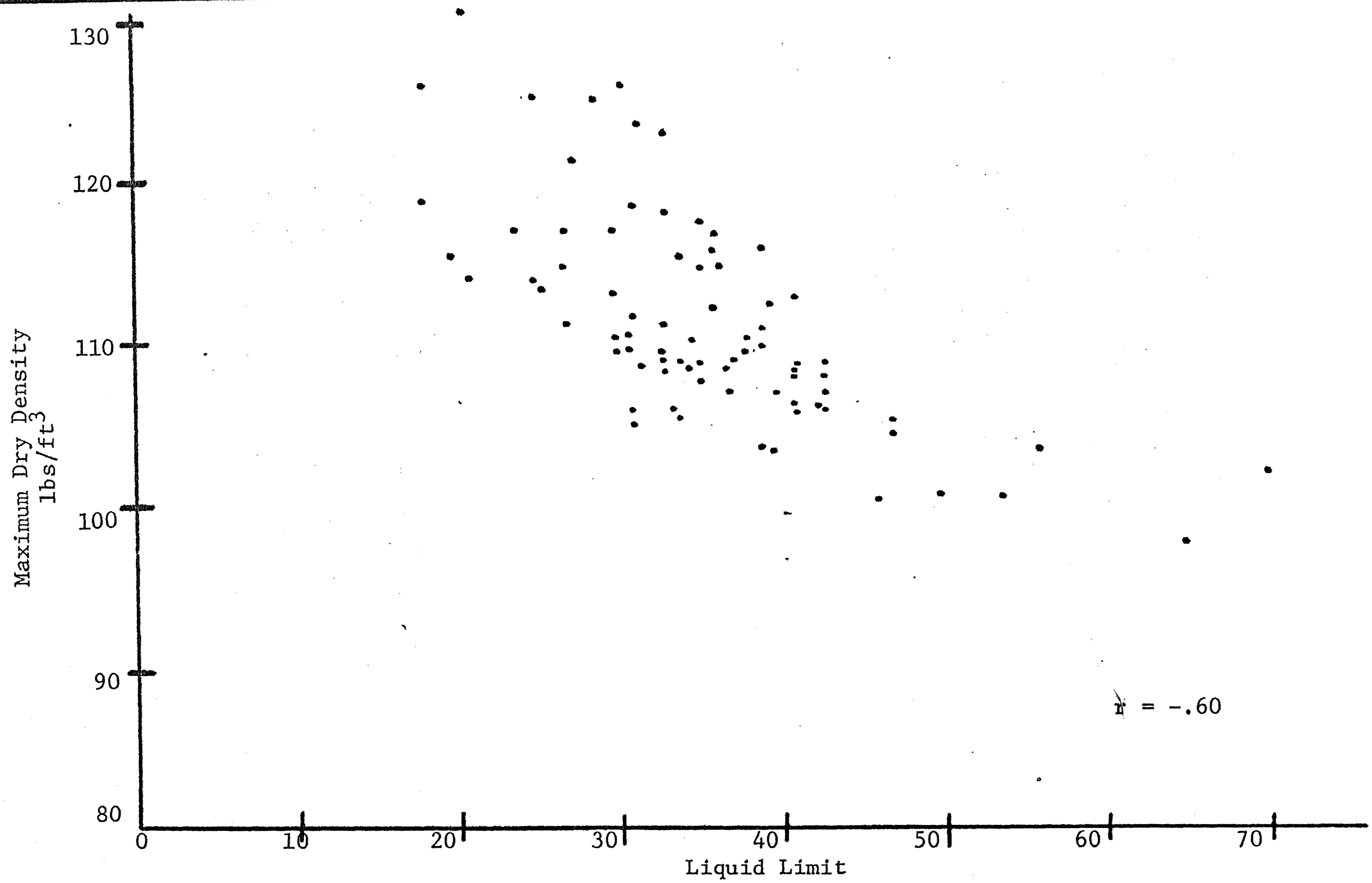


Figure 46. Maximum Dry Density Versus Liquid Limit
(Glacial Soils - Arithmetic Plot)

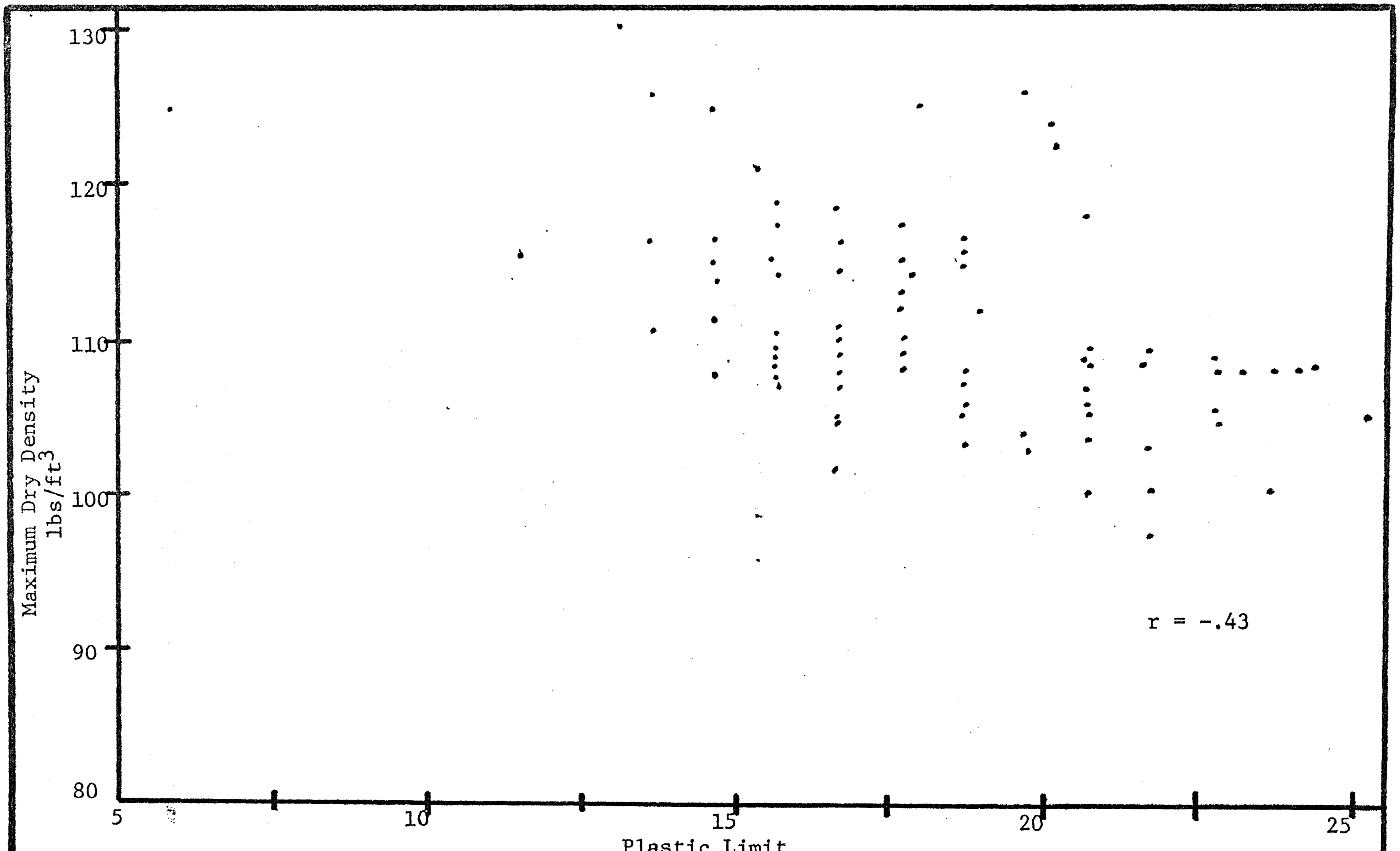


Figure 47. Maximum Dry Density Versus Plastic Limit
(Glacial Soils - Arithmetic Plot)

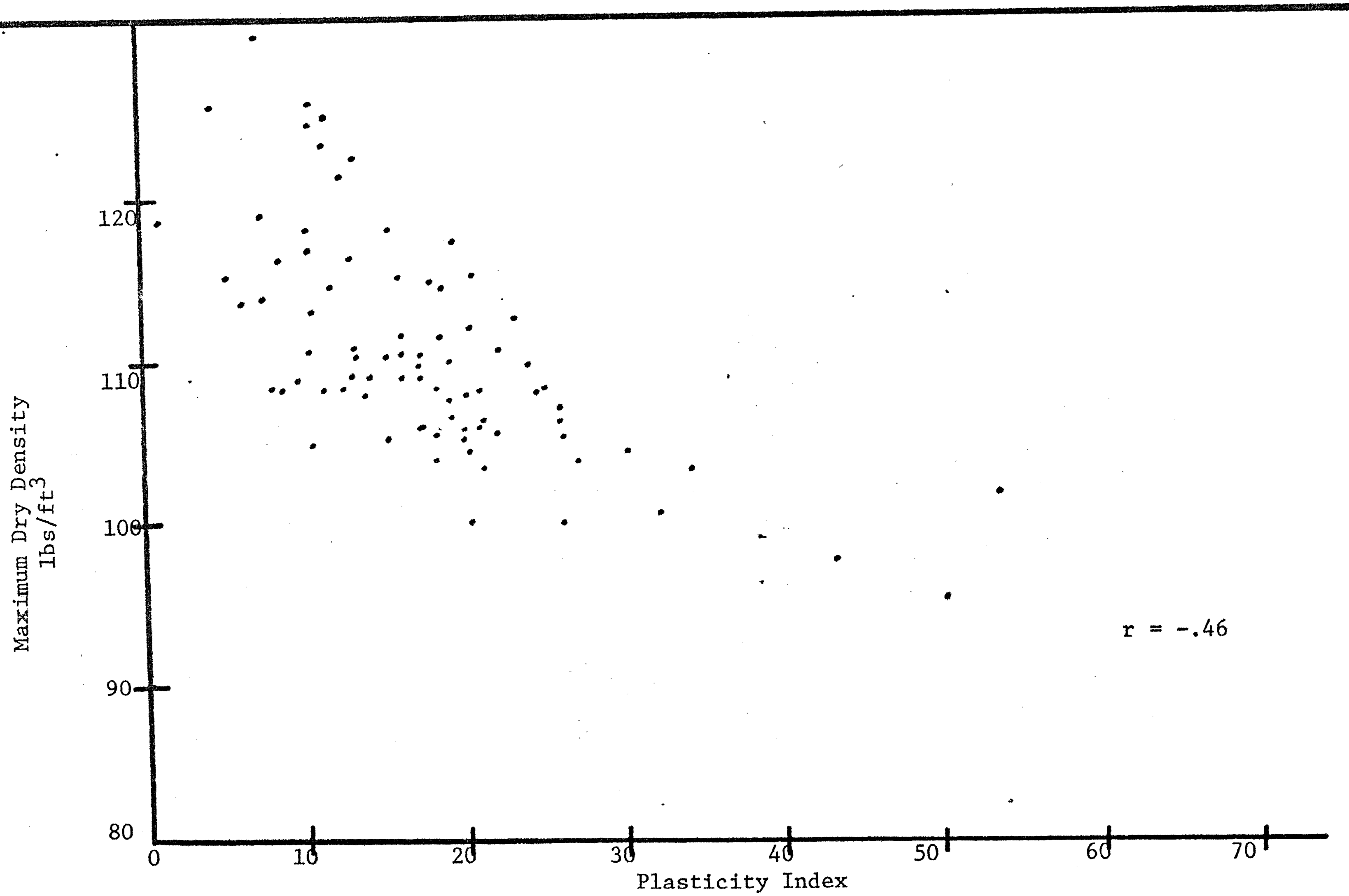


Figure 48. Maximum Dry Density Versus Plasticity Index
(Glacial Soils - Arithmetic Plot)

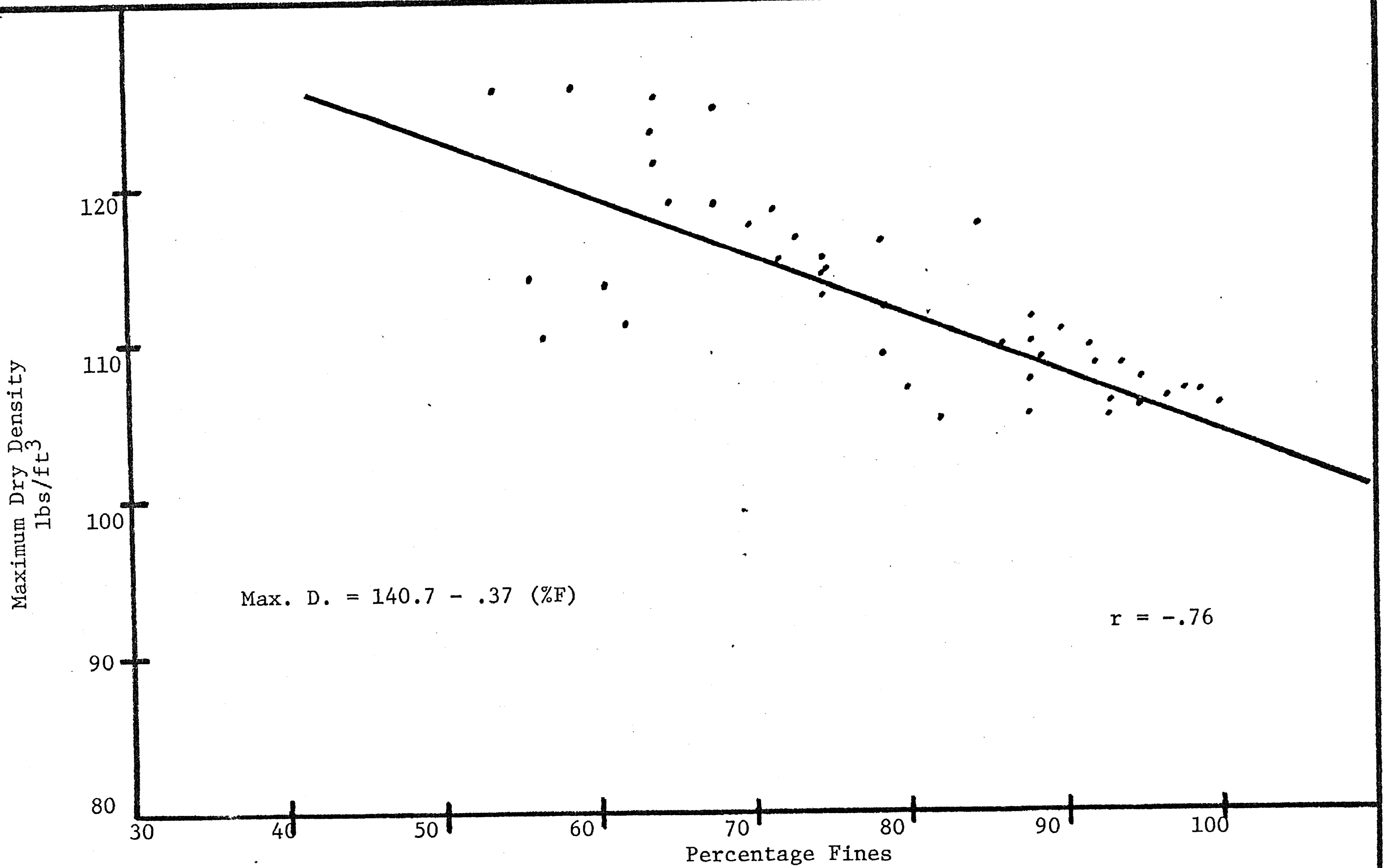


Figure 49. Maximum Dry Density Versus Percent Fines
(Glacial Soils - Arithmetic Plot)

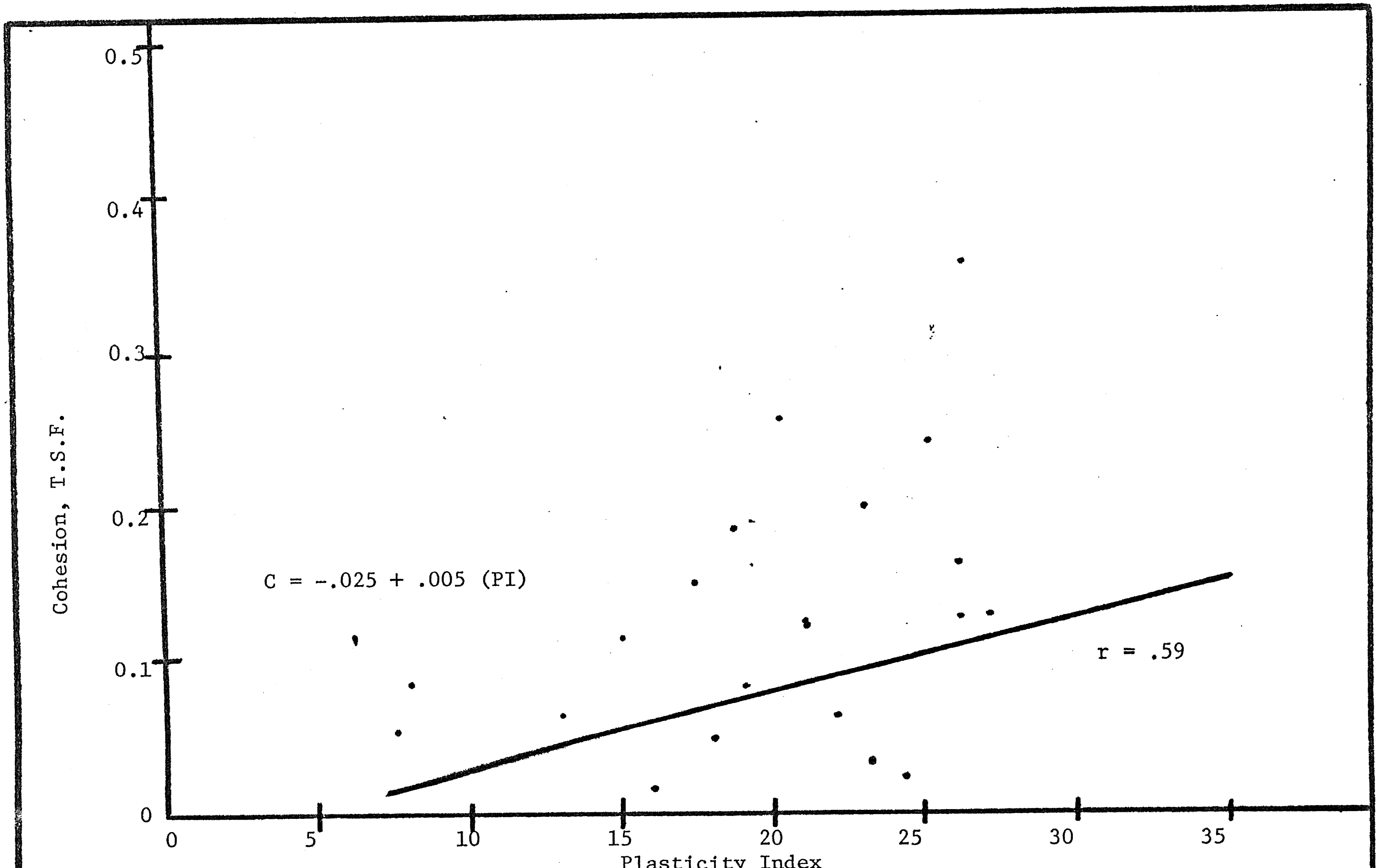


Figure 50. Glacial Soils Cohesion Versus Plasticity Index (Glacial Soils - Arithmetic Plot)

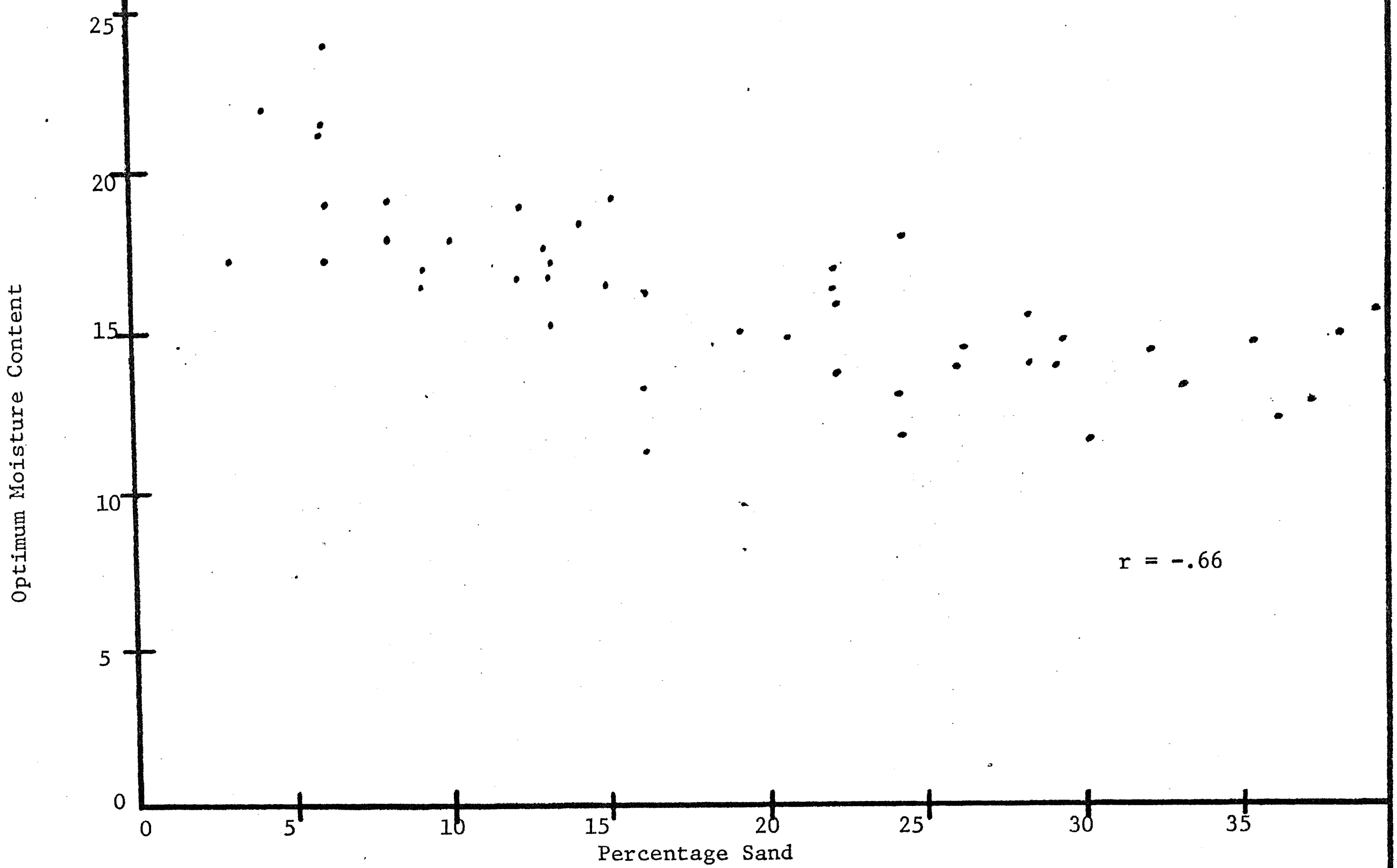


Figure 51. Optimum Moisture Content Versus Percent Fines
(Glacial Soils - Arithmetic Plot)

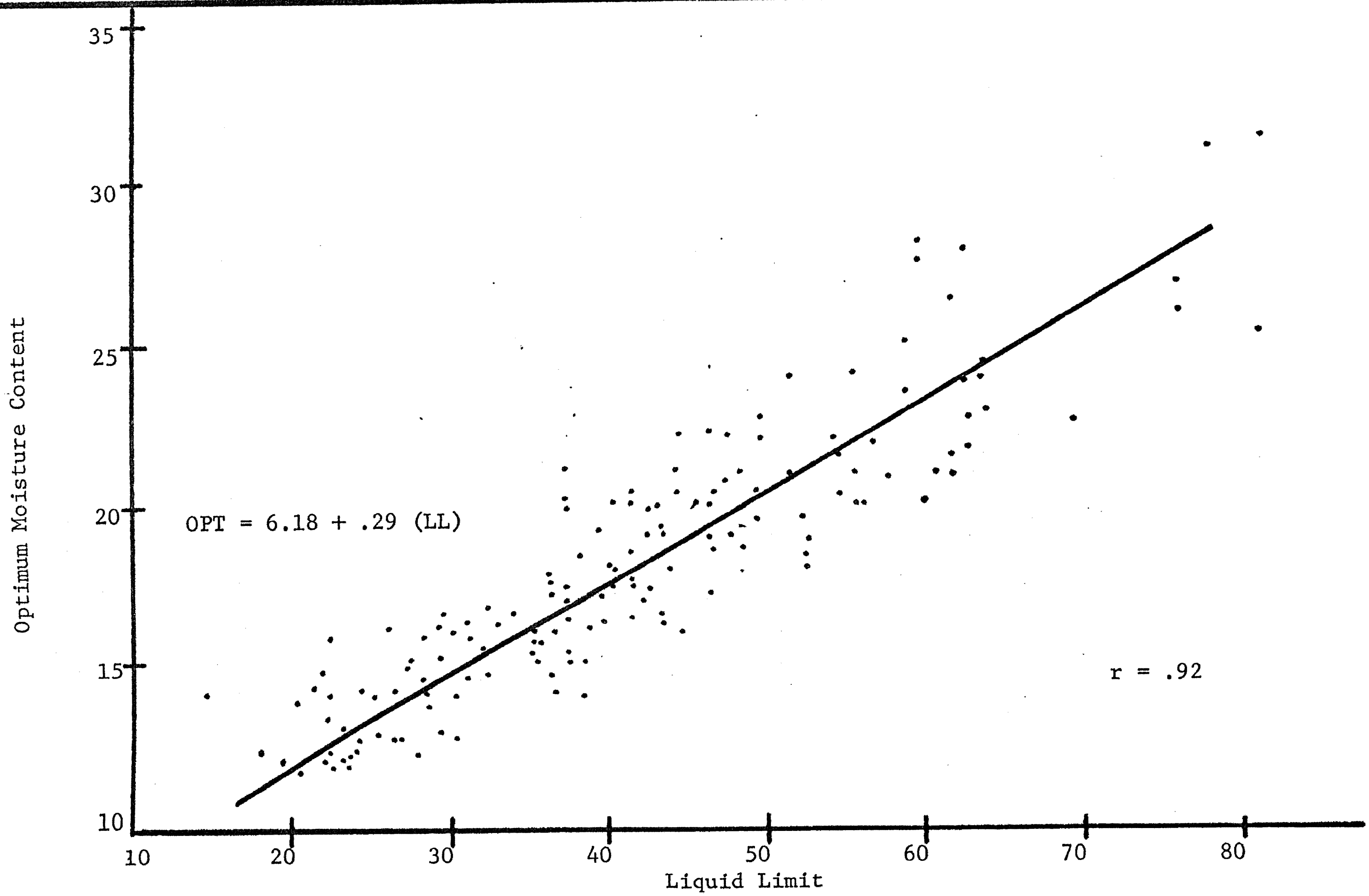


Figure 52. Optimum Moisture Content Versus Liquid Limit (Residual Soils - Arithmetic Plot)

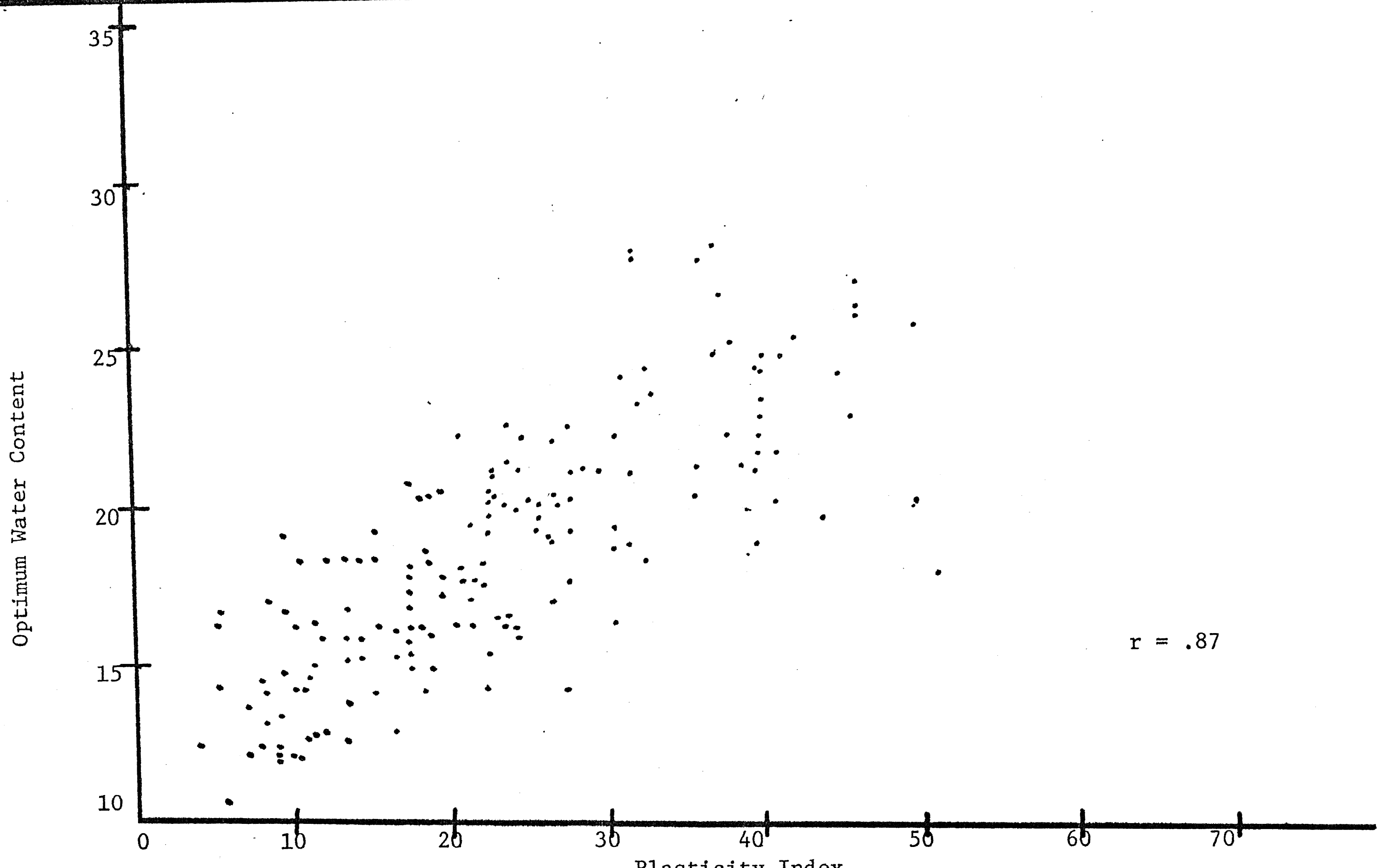


Figure 53. Residual Soils Optimum Moisture Content Versus Plasticity Index (Residual Soils - Arithmetic Plot)

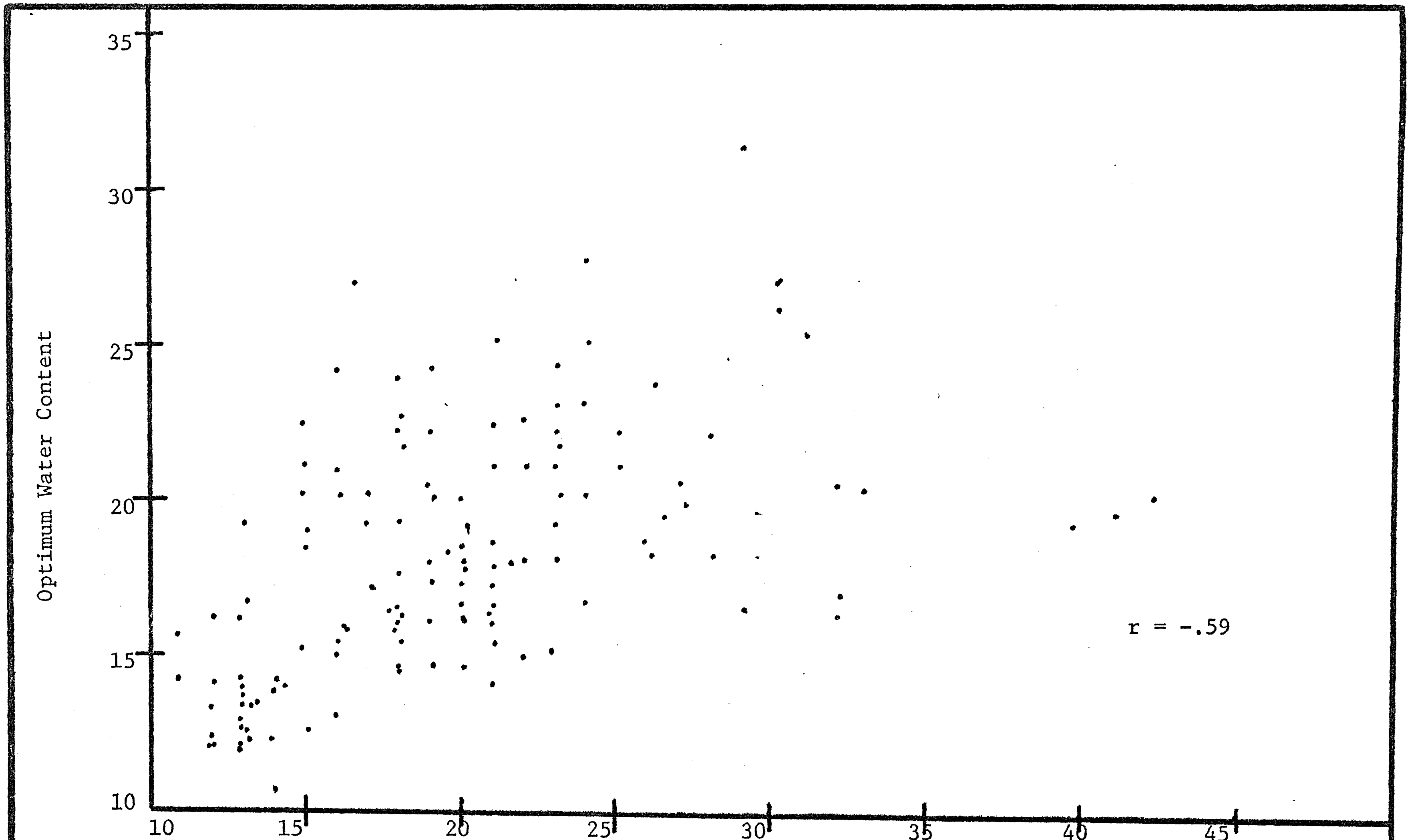


Figure 54. Optimum Water Content Versus Plastic Limit
(Residual Soils - Arithmetic Plot)

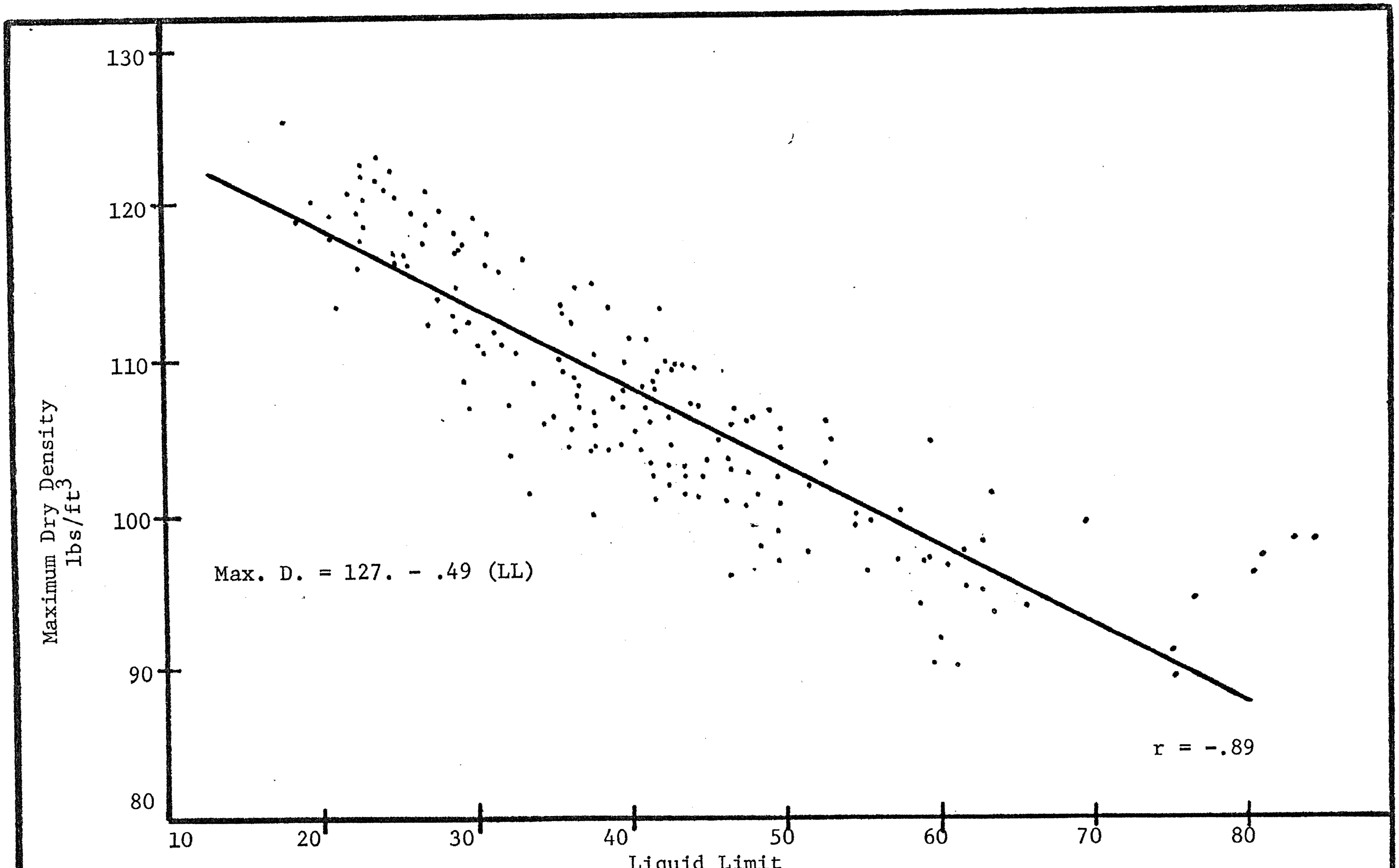


Figure 55. Maximum Dry Density Versus Liquid Limit
(Residual Soils - Arithmetic Plot)

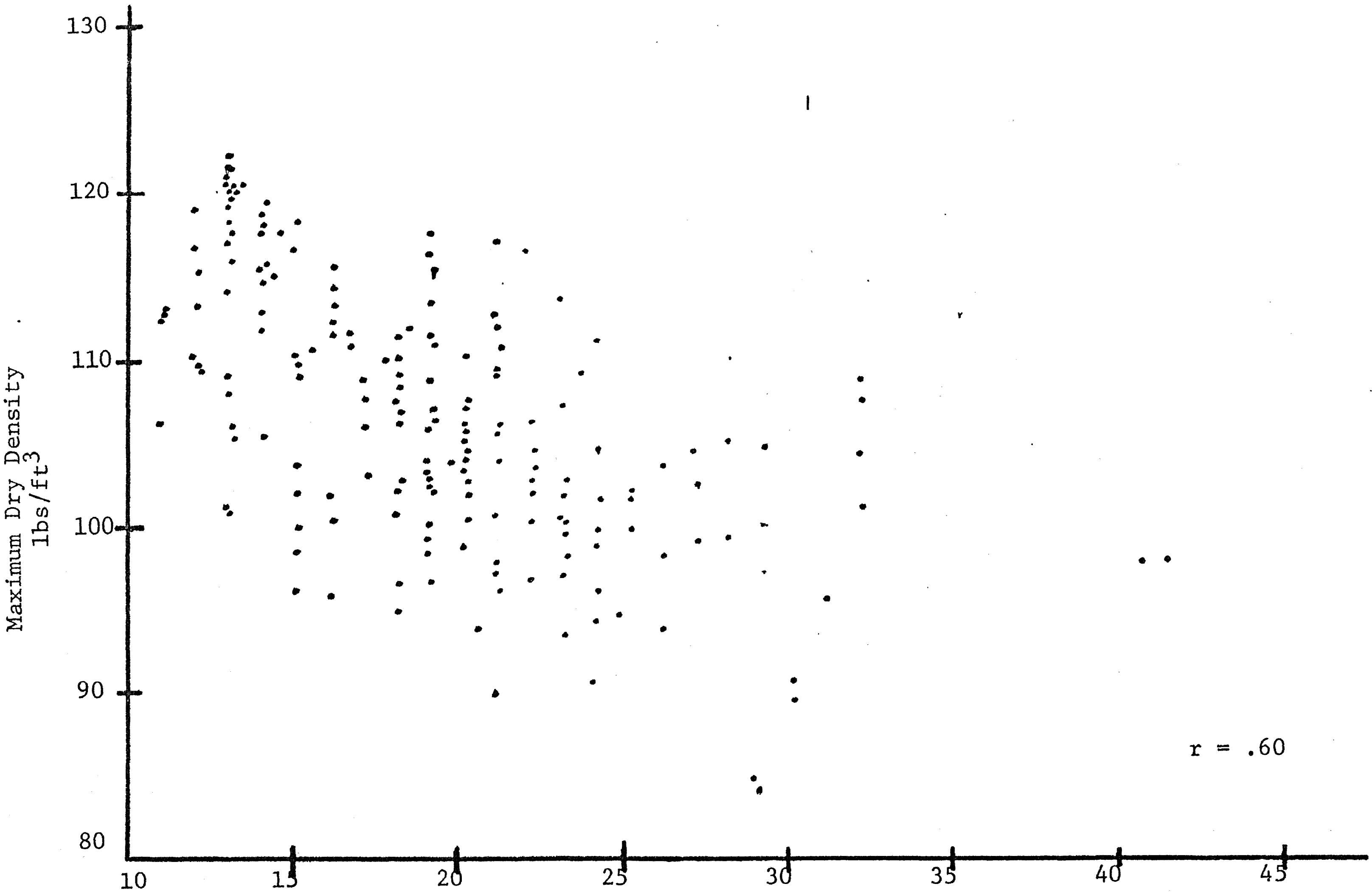


Figure 56. Maximum Dry Density Versus Plastic Limit
(Residual Soils - Arithmetic Plot)

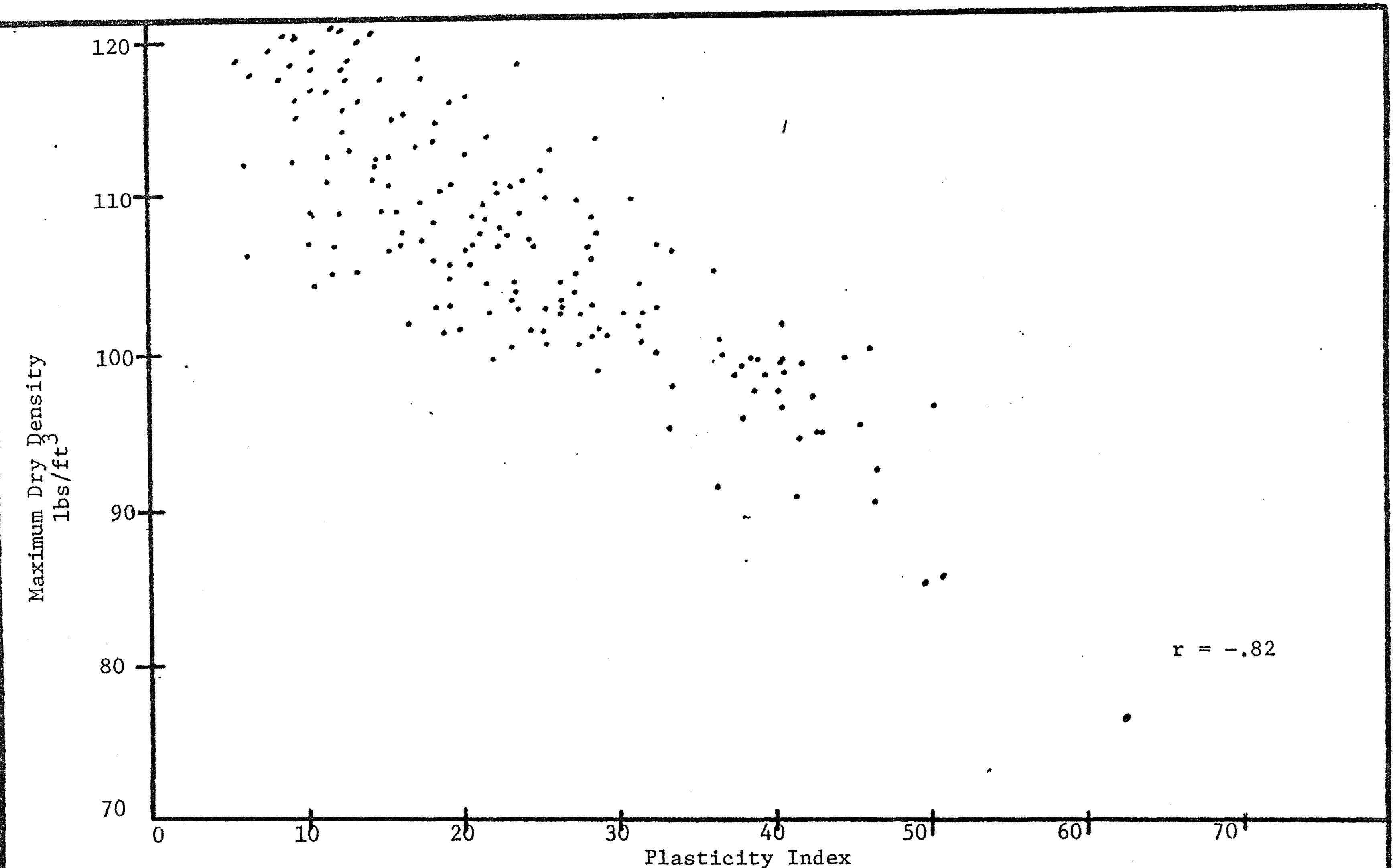


Figure 57. Maximum Dry Density Verses Plasticity Index
(Residual Soils - Arithmetic Plot)

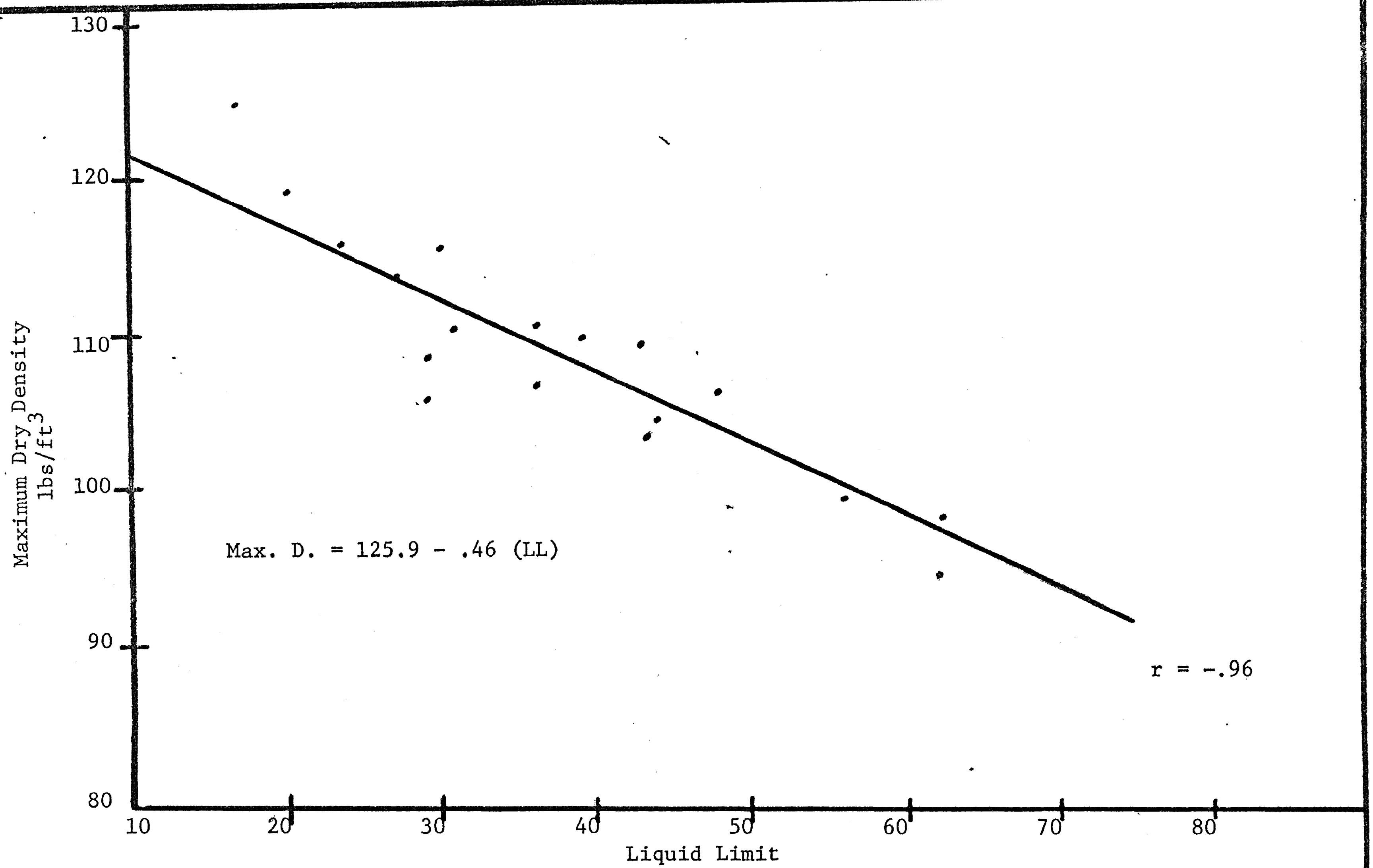


Figure 58. Maximum Dry Density Versus Liquid Limit (Meramec Park Soils - Arithmetic Plot)

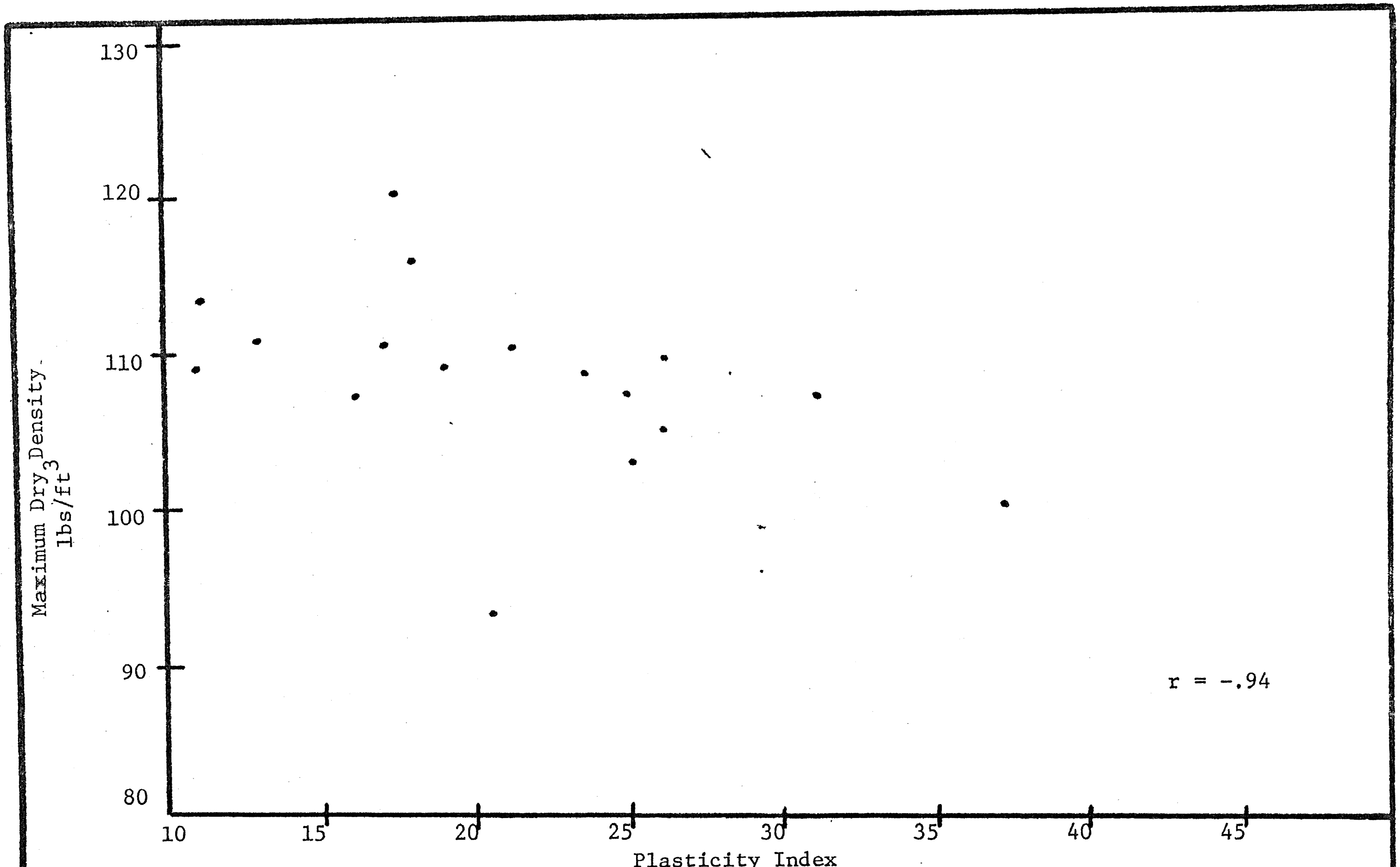


Figure 59. Maximum Dry Density Versus Plasticity Index
(Meramec Park Soils - Arithmetic Plot)

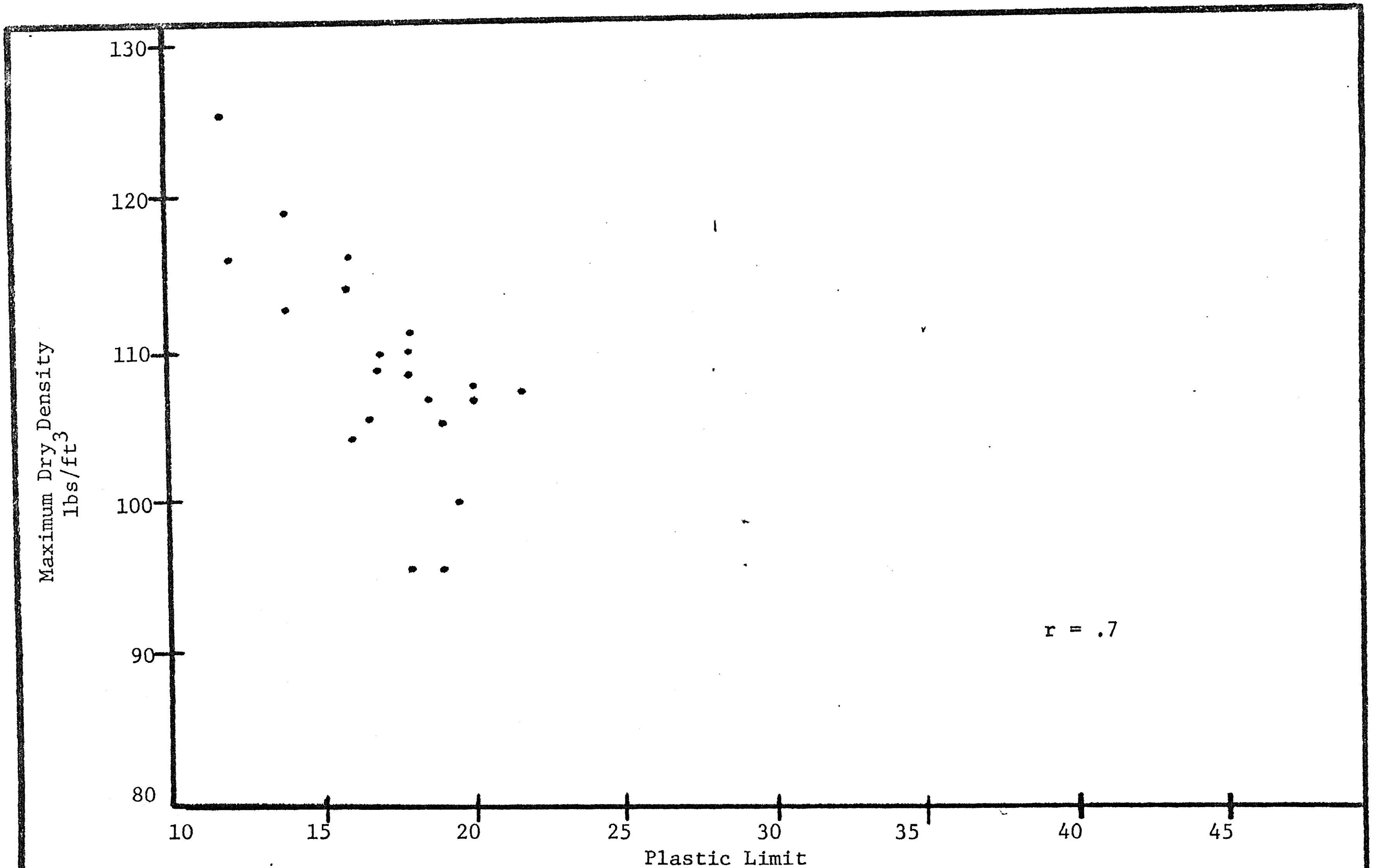


Figure 60. Maximum Dry Density Versus Plastic Limit
(Meramec Park Soils - Arithmetic Plot)

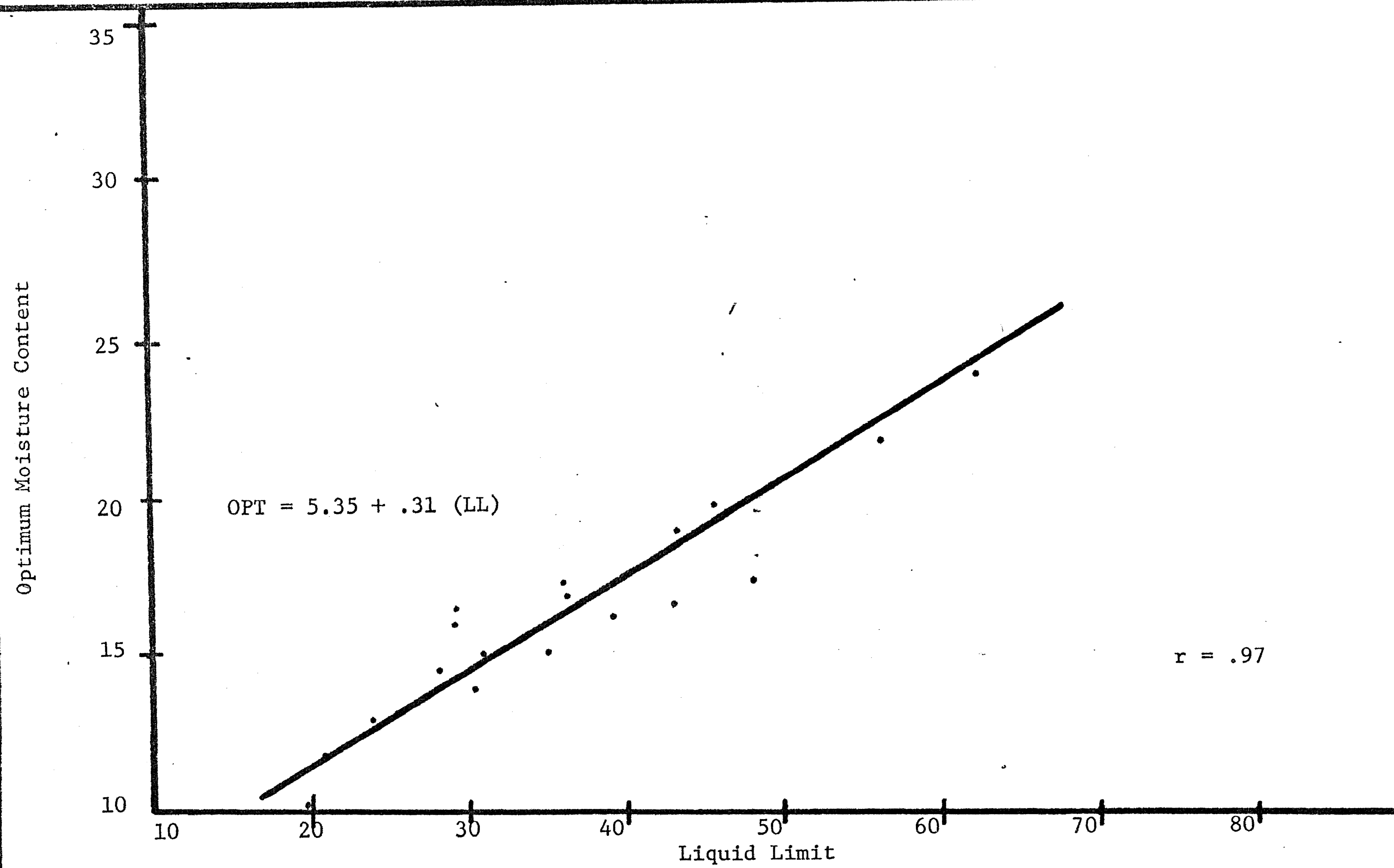


Figure 61. Optimum Moisture Content Versus Liquid Limit (Meramec Park Soils - Arithmetic Plot)

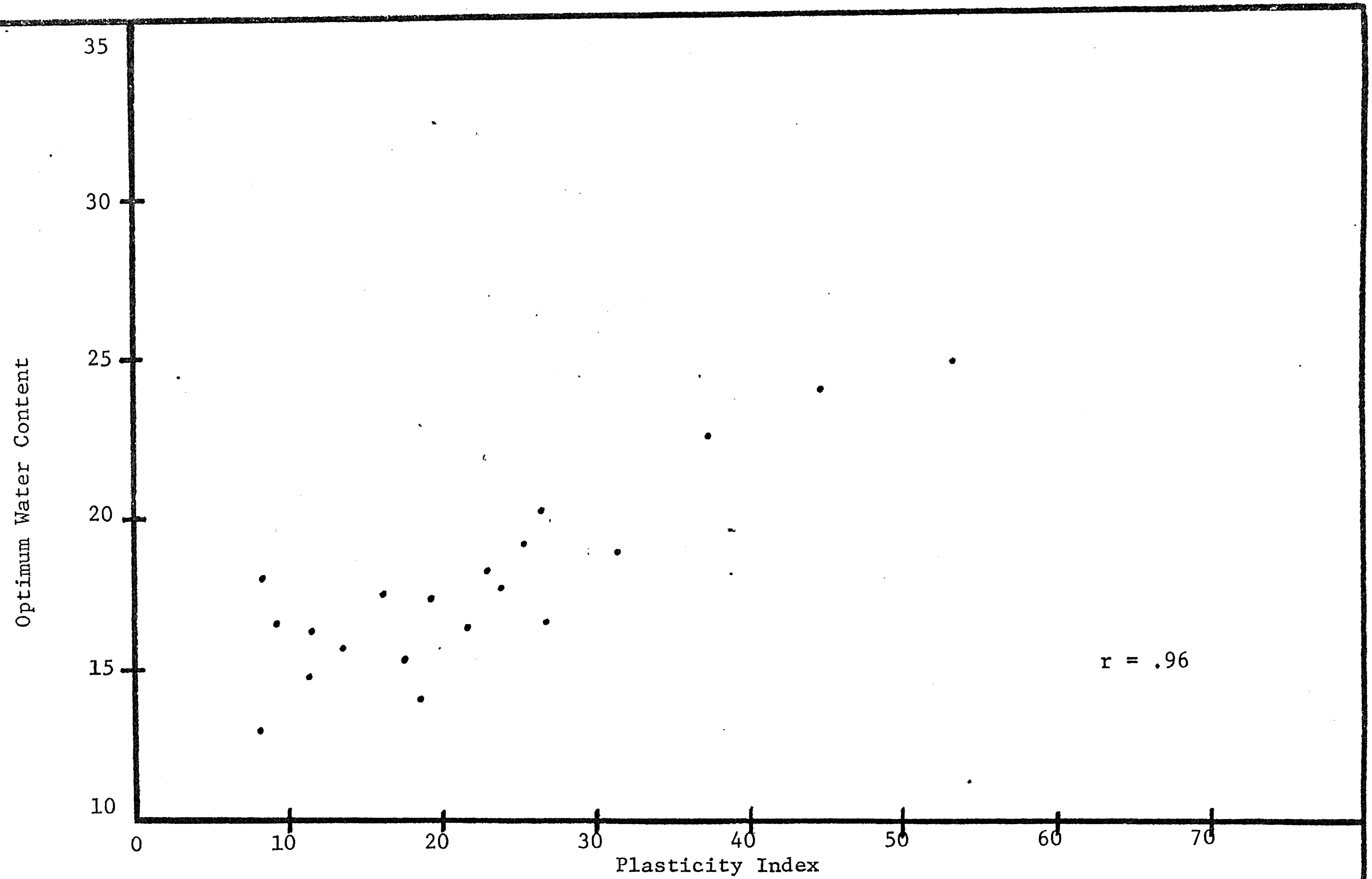


Figure 62. Optimum Moisture Content Versus Plasticity Index (Meramec Park Soils - Arithmetic Plot)

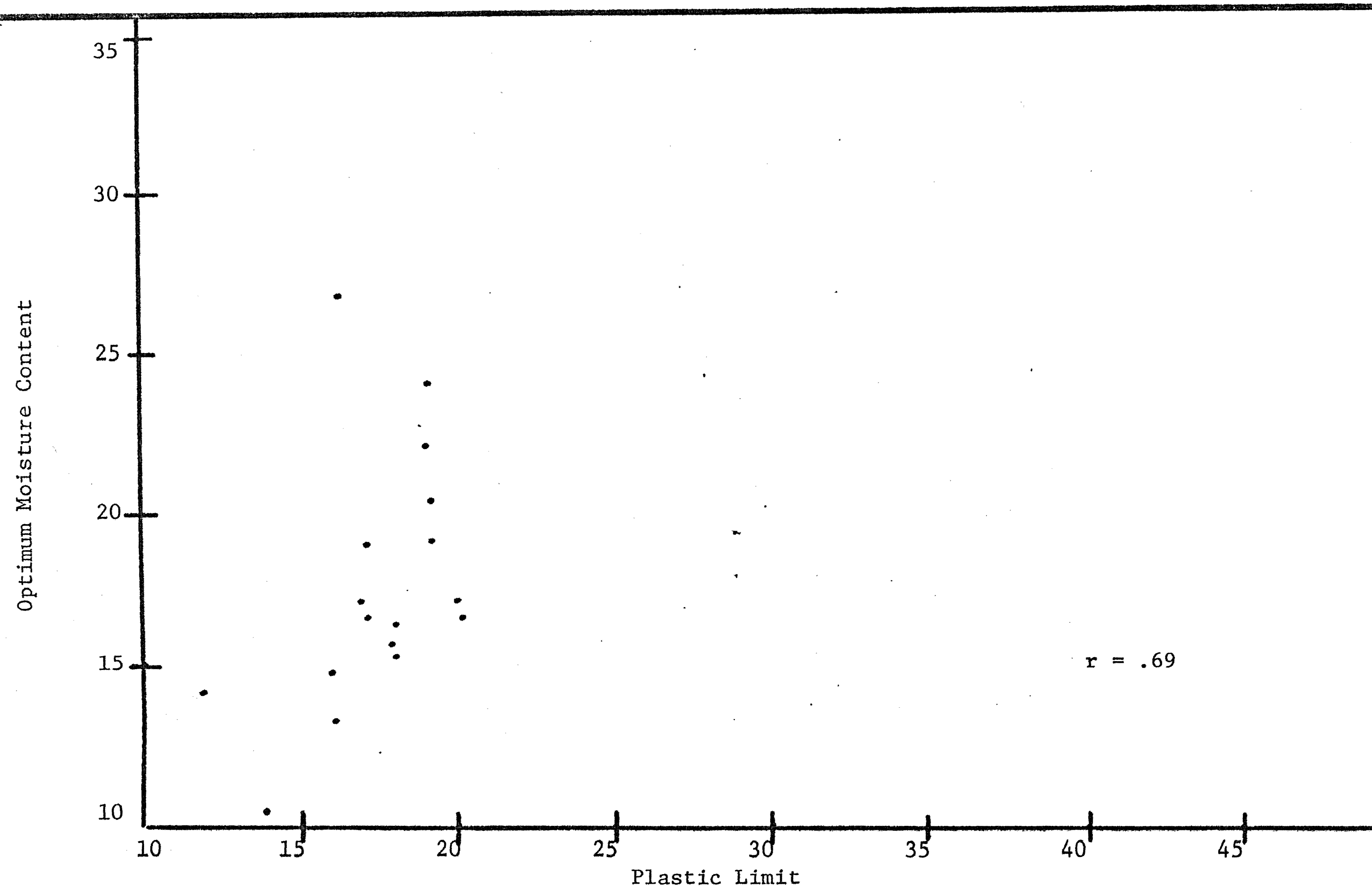


Figure 63. Optimum Moisture Content Versus Plastic Limit (Meramec Park Soils - Arithmetic Plot)

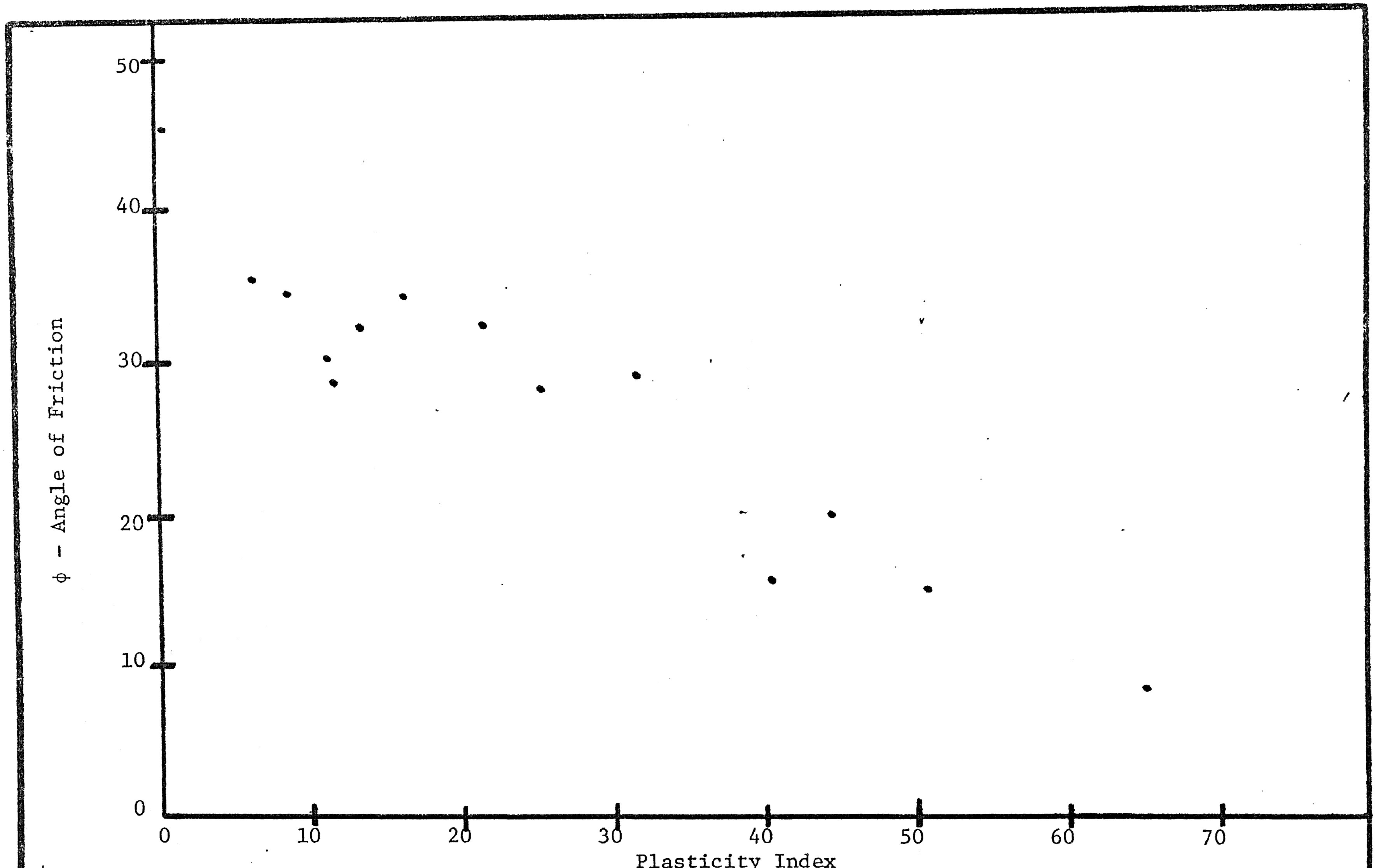


Figure 64. Angle of Friction Versus Plasticity Index
(Meramec Park Soils - Arithmetic Plot)

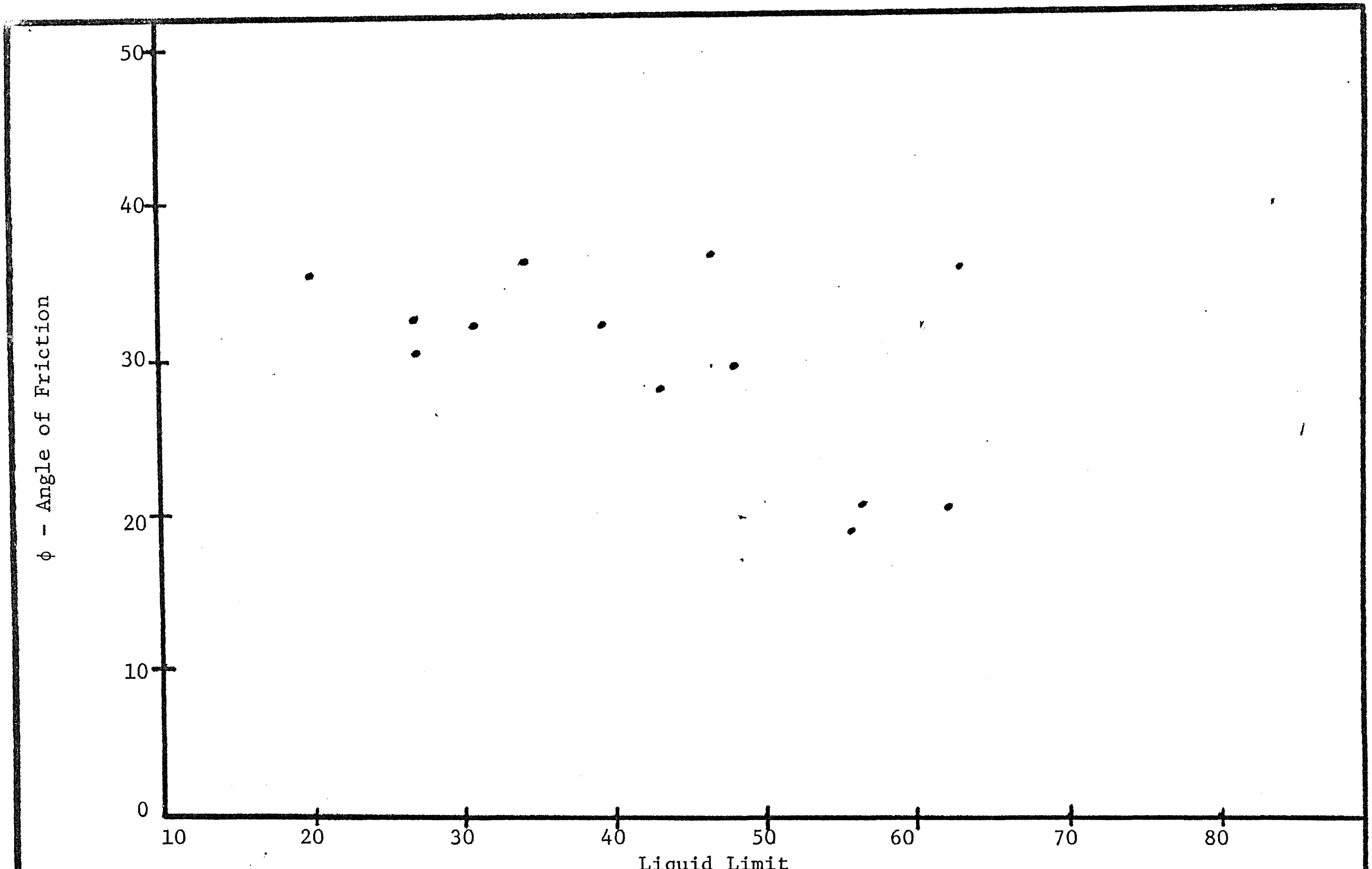


Figure 65. Angle of Friction Versus Liquid Limit
(Meramec Park Soils - Arithmetic Plot)

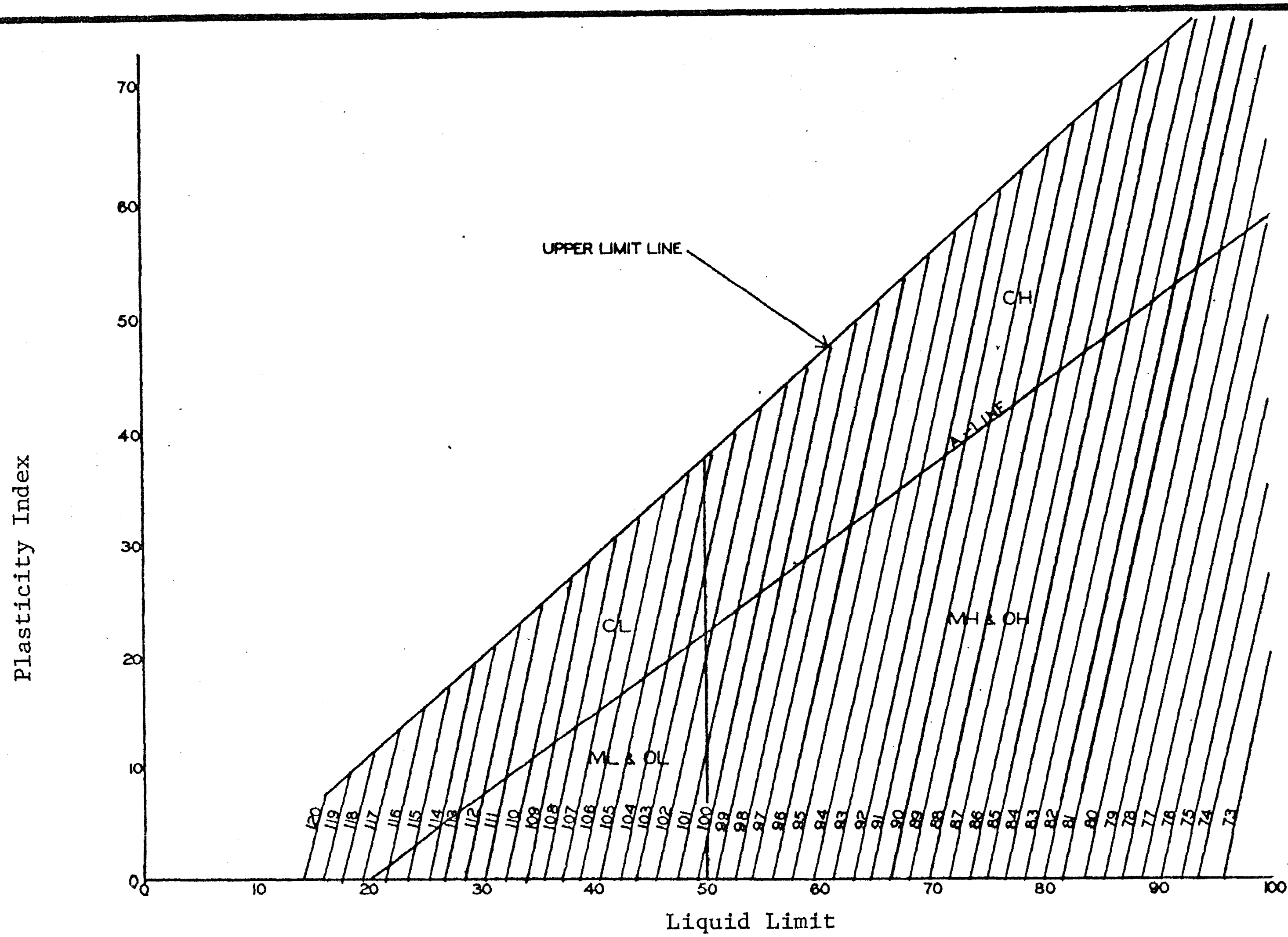


Figure 66. Graphical Relationship of Maximum Dry Density to the Plasticity Index and Liquid Limit

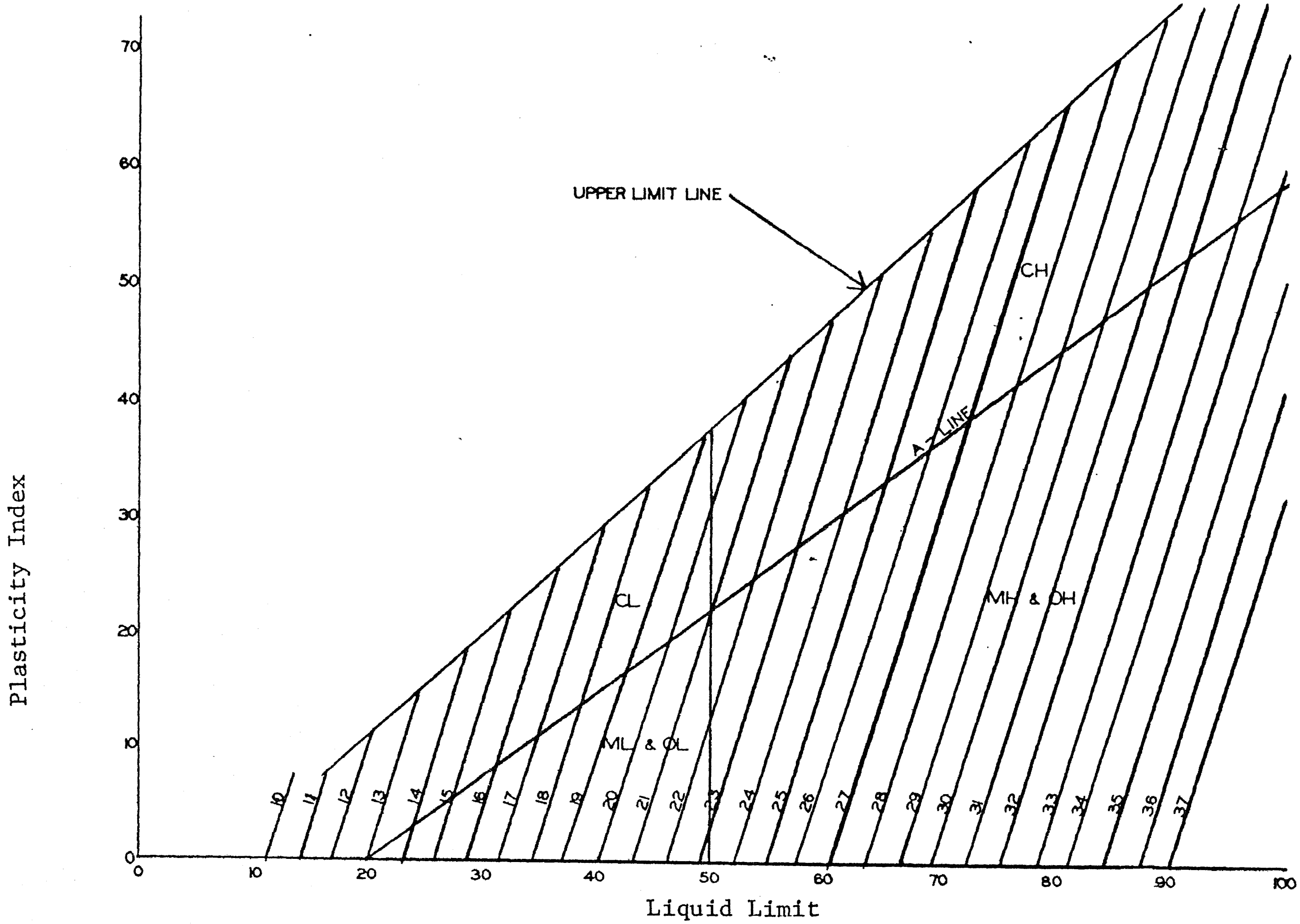


Figure 67. Graphical Relationship of Optimum Moisture Content to the Plasticity Index and Liquid Limit

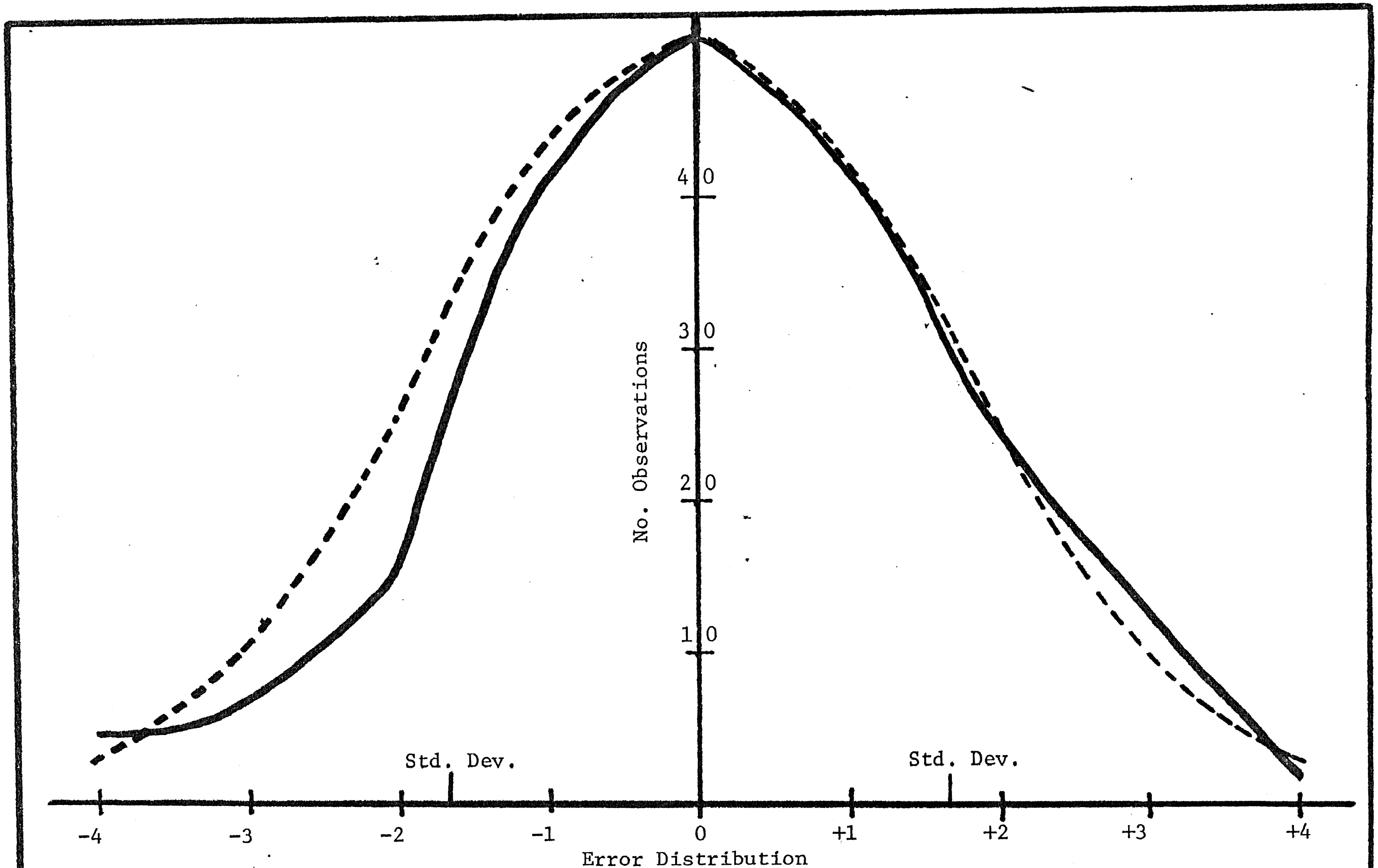


Figure 68. Predicted Versus Actual Optimum Moisture Content

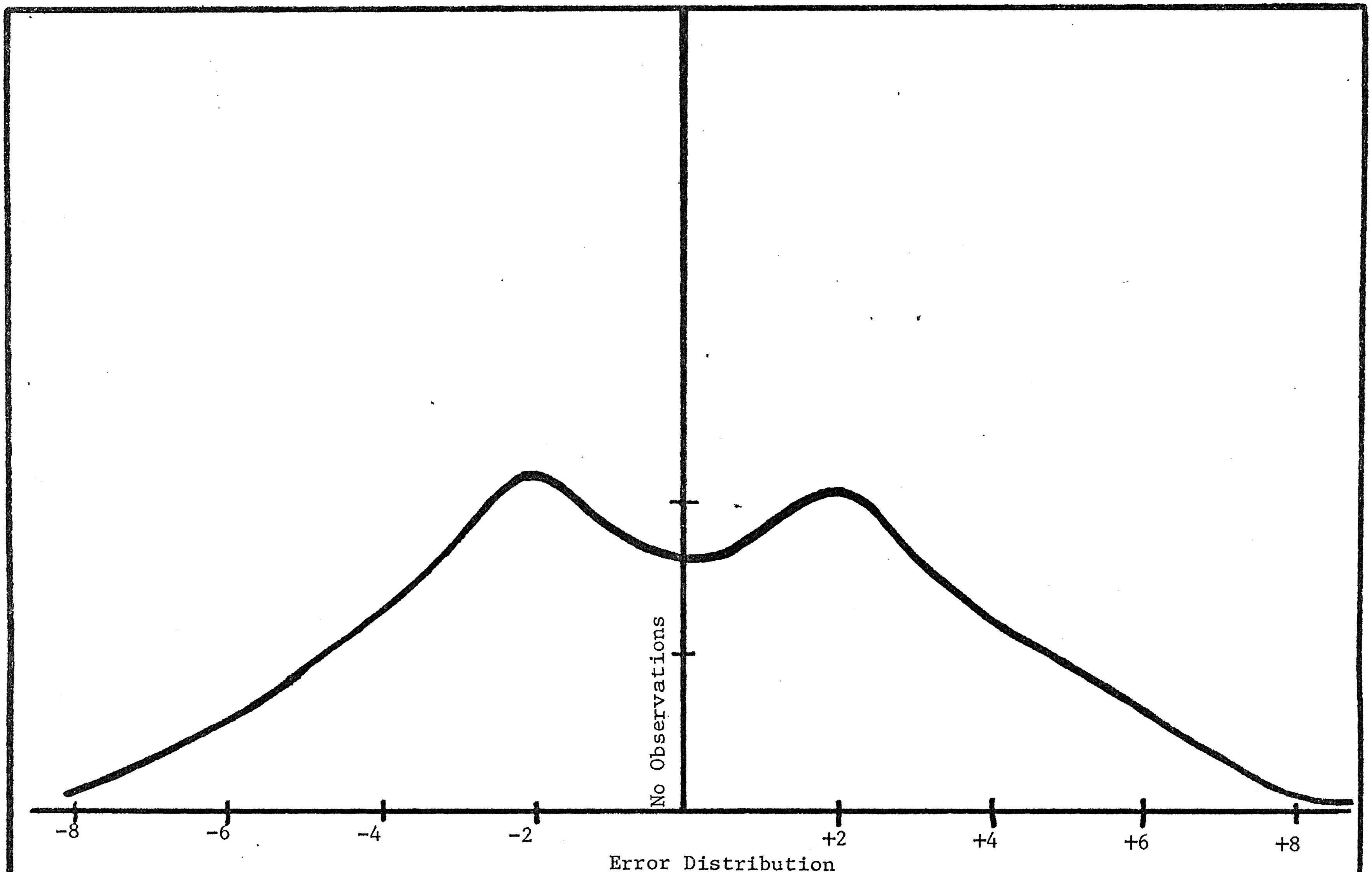


Figure 69. Predicted Versus Actual Maximum Dry Density

APPENDIX B

TABLES AND MISCELLANEOUS CHARTS

TABLE I
Simple Correlation Coefficients
Angle of Intenal Friction
Analysis 28 (All Soils)

	Ø	% F	AC	PI	Opt.	Max D.	WC
Ø	1.0						
% F	.22	1.0					
AC	.54	.06	1.0				
PI	.78	.28	.57	1.0			
Opt.	.61	.52	.38	.81	1.0		
Max D.	.60	.58	.39	.79	.96	1.0	
WC	.50	.46	.21	.68	.90	.85	1.0

Analysis 33 (All Soils)

	Ø	LL	PL	PI	Opt.	Max D.	WC
Ø	1.0						
LL	.65	1.0					
PL	.10	.61	1.0				
PI	.73	.94	.30	1.0			
Opt.	.50	.76	.54	.68	1.0		
Max D.	.56	.85	.57	.77	.86	1.0	
WC	.48	.76	.56	.67	.82	.86	1.0

TABLE I (CONTINUED)
Angle of Friction
Analysis 27 (Residual Soils)

	Ø	LL	PL	PI	Opt.	Max D.	WC
Ø	1.0						
LL	.59	1.0					
PL	.09	.67	1.0				
PI	.70	.93	.37	1.0			
Opt.	.61	.88	.55	.83	1.0		
Max D.	.61	.88	.58	.82	.95	1.0	
WC	.55	.82	.53	.76	.92	.89	1.0

Analysis 26 (Glacial Soils)

	Ø	LL	PL	PI	Opt.
Ø	1.0				
LL	.70	1.0			
PL	.01	.34	1.0		
PI	.75	.94	.03	1.0	
Opt.	.42	.75	.50	.65	1.0

TABLE II
Simple Correlation Coefficients
Maximum Dry Density
Equation #10 (All Soils)

	Max d.	% S	% F	LL	PL	PI
Max d.	1.0					
% S	.41	1.0				
% F	.46	.97	1.0			
LL	.85	.32	.33	1.0		
PL	.59	.09	.09	.58	1.0	
PI	.76	.34	.36	.94	.28	1.0

Equation #11 (All Soils)

	Max d.	% S	% F	S.G.	LL
Max d.	1.0				
% S	.41	1.0			
% F	.46	.97	1.0		
S.G.	.14	.06	.01	1.0	
LL	.86	.32	.34	.04	1.0

Simple Correlation Coefficients
Maximum Dry Density
Equation #21 (Residual Soils)

	Max d.	% S	% F	LL	PL	PI
Max d.	1.0					
% S	.39	1.0				
% F	.39	.99	1.0			
LL	.89	.33	.32	1.0		
PL	.60	.06	.06	.63	1.0	
PI	.82	.41	.41	.94	.34	1.0

TABLE II (CONTINUED)
Equation #22 (Glacial Soils)

	Max d.	% S	% F	LL	PL	PI
Max d.	1.0					
% S	.66	1.0				
% F	.76	.89	1.0			
LL	.60	.56	.46	1.0		
PL	.43	.39	.21	.54	1.0	
PI	.46	.44	.41	.88	.07	1.0

Maximum Dry Density
Equation #24 (Coastal Plains Soils)

	Max d.	% S	% F	LL	PI
Max d.	1.0				
% S	.76	1.0			
% F	.76	.98	1.0		
LL	.81	.76	.76	1.0	
PI	.57	.60	.59	.91	1.0

TABLE III
Simple Correlation Coefficients
Cohesion
Analysis 2 (All Soils)

	C	% F	AC	PI	Opt.	Max d.	W.C.
C	1.0						
% F	.01	1.0					
AC	.22	.04	1.0				
PI	.26	.30	.57	1.0			
Opt.	.13	.53	.36	.81	1.0		
Max D.	.15	.59	.38	.79	.96	1.0	
W.C.	.07	.46	.21	.68	.90	.85	1.0

Analysis 8 (All Soils)

	C	LL	PL	PI	Opt.	Max D.	W.C.
C	1.0						
LL	.05	1.0					
PL	.22	.61	1.0				
PI	.02	.94	.30	1.0			
Opt.	.08	.86	.57	.79	1.0		
Max D.	.08	.85	.57	.77	.95	1.0	
W.C.	.16	.76	.56	.67	.90	.86	1.0

TABLE III (CONTINUED)

Cohesion

Analysis #1 (Glacial Soils)

	C	LL	PL	PI	Opt.
C	1.0				
LL	.56	1.0			
PL	.01	.33	1.0		
PI	.59	.95	.03	1.0	
Opt.	.34	.76	.50	.65	1.0

Analysis #9 (Residual Soils)

	C	LL	PL	PI	Opt.	Max D.	W.C.
C	1.0						
LL	.18	1.0					
PL	.27	.67	1.0				
PI	.10	.93	.36	1.0			
Opt.	.16	.88	.55	.83	1.0		
Max D.	.21	.86	.58	.81	.95	1.0	
W.C.	.25	.82	.53	.76	.92	.89	1.0

TABLE IV

Simple Correlation Coefficients
Optimum Moisture Content
Analysis 35 (All Soils)

	Opt.	AC	LL	PL	PI
Opt.	1.0				
AC	.42	1.0			
LL	.90	.53	1.0		
PL	.66	.08	.59	1.0	
PI	.83	.60	.97	.38	1.0

Analysis 36 (All Soils)

	Opt.	% S	% F	LL	PL	PI
Opt.	1.0					
% S	.40	1.0				
% F	.43	.97	1.0			
LL	.89	.32	.33	1.0		
PL	.62	.09	.09	.09	1.0	
PI	.80	.34	.35	.94	.28	1.0

Optimum Moisture Content
Analysis 48 (Residual Soils)

	Opt.	% S	% F	LL	PL	PI
Opt.	1.0					
% S	.36	1.0				
% F	.36	1.0	1.0			
LL	.92	.32	.32	1.0		
PL	.59	.06	.06	.63	1.0	
PI	.87	.41	.40	.94	.34	1.0

TABLE IV (CONTINUED)

Analysis 49 (Glacial)

	Opt.	% S	% F	LL	PL	PI
Opt.	1.0					
% S	.66	1.0				
% F	.71	.89	1.0			
LL	.64	.56	.46	1.0		
PL	.58	.39	.21	.21	1.0	
PI	.43	.44	.41	.88	.07	1.0

Analysis 51 (Coastal Plains Soils)

	Opt.	% S	% F	LL	PL
Opt	1.0				
% S	.81	1.0			
% F	.80	.98	1.0		
LL	.81	.76	.76	1.0	
PL	.85	.85	.61	.81	1.0

TABLE V - SUMMARY OF SOIL TEST DATA

Observation No.		Primary Soil Division	Laboratory Classification (Unified Soil)	Mechanical Analysis: Gravel	Sand	Fines	%Clay	Sp. Gr.	Act. Coeff.	LL	PL	PI	Compaction Data: Opt. Water	Max. Dry Density	Shear - Data: Type Test	WC	C	Ø	Project
1	BA-1	Glacial	Sandy Clay CL	3	30	67	-	2.74	-	24	14	10	11.2	124.5	DS	8.1	.03	31	Shelbyville
2	BA-2	Glacial	Sandy Clay CL	2	29	69	-	2.71	-	35	15	20	14.2	114.9	DS	-	-	-	Shelbyville
3	BA-3	Glacial	Grs, Clay (CL)	3	26	71	-	2.73	-	32	17	15	13.5	117.7	DS	9.7	0	29	Shelbyville
4	BB-1	Glacial	S. Clay (CL)	10	16	74	-	2.73	-	40	17	23	10.0	112.4	DS	12.7	.03	29	Shelbyville
5	BB-1	Glacial	S. Clay (CL)	1	25	74	-	2.70	-	34	16	18	15.5	114.0	DS	-	-	-	Shelbyville
6	BC-3	Glacial	S. Clay (CL)	3	28	69	-	2.74	-	34	15	14	15.0	117.0	DS	-	-	-	Shelbyville
7	BC-1	Glacial	S. Clay CL-ML	0	47	53	-	2.72	-	17	13	4	10.5	125.4	DS	6.8	0	32	Shelbyville
8	29-1	Residual	Clay (CL)	0	0	94	31	2.66	.80	43	18	25	19.1	102.7	DS	21.1	0.1	28	Meramec
9	20-2	Residual	Clay (CH)	0	7	93	45	2.68	.98	62	18	44	23.9	95.1	DS	25.2	0.14	20	Meramec
10	26-1	Residual	Sandy Clay CH	0	27	73	58	2.71	1.38	111	31	80	36.6	80.0	DS	39.0	0.19	21	Meramec
11	33-1	Residual	Sandy Clay CL	0	26	74	20	2.66	.55	27	16	11	14.8	113.5	DS	17.5	0.18	30	Meramec
12	9C-1	Residual	Sandy Clay CL	0	44	56	16	2.65	.50	24	16	8	13.0	115.4	DS	15.0	0.18	34	Meramec
13	56-1	Residual	Clay CL	0	2	98	25	2.60	.64	36	20	16	17.5	106.7	DS	20.6	0	34	Meramec
14	29-3	Residual	Clay CH	0	12	88	42	2.74	1.73	99	26	73	41.0	76.5	DS	-	-	-	Meramec
15	41-1	Residual	Clay CH	0	24	76	33	2.66	.98	56	19	37	22.0	99.4	DS	-	-	-	Meramec
16	167-2	Residual	Clay CL	0	26	74	35	2.68	.89	48	17	31	18.8	106.4	DS	21.7	0	24	Meramec
17	27-1	Residual	S. Clay CL	0	33	77	26	2.66	.69	30	12	18	14.0	115.6	DS	-	-	-	Meramec
18	31-1	Residual	Clay CL	0	8	92	14	2.66	.64	29	20	9	16.4	106.5	DS	-	-	-	Meramec
19	179-1	Residual	Clay CL	0	10	90	29	2.66	.45	31	18	13	15.7	110.5	DS	18.0	.04	32	Meramec
20	167-1	Residual	Clay CL	0	8	92	31	2.68	.61	36	17	19	17.1	108.3	DS	-	-	-	Meramec
21	174-3	Residual	S. Clay CL	0	28	72	32	2.66	.81	43	17	26	16.7	100.3	DS	-	-	-	Meramec
22	23-2	Residual	Clay CL	0	14	86	27	2.68	.96	45	19	26	20.1	104.7	DS	-	-	-	Meramec
23	215-1	Residual	S. Clay (CL-ML)	0	32	68	6	2.74	.83	17	12	5	9.5	124.2	DS	-	-	-	Meramec
24	31-2	Residual	S. Clay CL	0	3	97	23	2.66	.74	35	18	17	15.3	109.8	DS	-	-	-	Meramec
25	142-1	Residual	Clay CL	0	24	76	24	2.66	.46	29	18	11	16.2	108.9	DS	-	-	-	Meramec
26	71-1	Residual	S. Clay (CL-ML)	0	45	55	14	2.64	.43	20	14	6	10.5	118.7	DS	13.5	0	35	Meramec
27	72-2	Residual	Clay CL	0	18	82	30	2.68	.70	39	18	21	16.3	109.7	DS	19.2	0	32	Meramec
28	P-42	Glacial	Clay CH	-	-	-	-	2.72	-	69	16	53	21.3	101.6	DS	24.5	0.25	11	Cannon
29	P-41	Glacial	Clay CL	-	-	-	-	2.69	-	42	16	26	18.7	105.2	DS	21.0	0.16	24	Cannon
30	P-3	Glacial	Silty Clay CL	-	-	-	-	2.69	-	40	14	26	17.6	107.5	DS	19.7	.05	21	Cannon
31	P-2	Glacial	Clay CL	-	-	-	-	2.72	-	46	16	30	18.8	104.6	DS	20.7	.10	25	Cannon
32	555-B1	Glacial	S. Clay CL	0	12	88	-	2.68	-	36	15	21	16.3	108.0	DS	17.8	0.12	28	Cannon
33	555-B2	Glacial	S. Clay CL	0	13	87	-	2.68	-	36	15	21	17.1	106.7	DS	17.4	.12	29	Cannon
34	560-B1	Glacial	Silty Clay CL	0	8	92	-	2.66	-	40	18	22	17.6	105.7	DS	-	-	-	Cannon
35	561-B1	Glacial	S. Clay CL	0	22	78	-	2.68	-	32	10	16	16.3	108.8	DS	18.0	.02	32	Cannon
36	567	Glacial	S. Clay CL	0	16	84	-	2.67	-	23	13	10	12.8	116.5	DS	14.5	.02	34	Cannon

TABLE V - SUMMARY OF SOIL TEST DATA

Observation No.		Primary Soil Division	Laboratory Classification (Unified Soil)	Mechanical Analysis Gravel	Sand	Fines	%Clay	Sp. Gr.	Act. Coeff.	LL	PL	PI	Compaction Data Opt. Water	Max.Dry Density	Shear - Data Type Test	WC	C	ø	Project
37	574	Glacial	Clayey Silt ML	0	29	71	22	2.67	.22	19	14	5	13.5	114.9	DS	15.5	0	36	Cannon
38	574-2	Glacial	S. Clay CL	0	22	78	25	2.67	.64	30	14	16	15.4	111.4	DS	-	-	-	Cannon
39	575-B2	Glacial	Clay CL	0	9	91	31	2.67	.55	32	15	17	16.1	108.8	DS	-	-	-	Cannon
40	576-B1	Glacial	S. Clay CL	0	39	61	18	2.67	.72	26	13	13	15.3	110.6	DS	-	-	-	Cannon
41	577-B1	Glacial	S. Clay CL	0	13	87	27	2.66	.59	32	16	16	14.8	110.7	DS	-	-	-	Cannon
42	577-B2	Glacial	Clay CL	0	7	93	29	2.66	.62	32	14	18	12.4	107.9	DS	-	-	-	Cannon
43	579-B2	Glacial	S. Clay CL	0	11	89	25	2.66	.52	29	16	13	15.2	110.1	DS	-	-	-	Cannon
44	589-B1	Glacial	Silty Clay CL	0	0	94	31	2.68	.61	34	15	19	17.0	107.3	DS	-	-	-	Cannon
45	573-B1	Glacial	S. Clay CL	0	36	64	17	2.66	.41	22	15	7	12.1	118.7	DS	14	0	35	Cannon
46	575-B1	Glacial	S.Clay.Silt (CL-ML)	0	26	74	23	2.67	.26	20	14	6	14.0	113.7	DS	15.2	0	32	Cannon
47	578-B1	Glacial	S. Clay CL	0	15	85	27	2.67	.48	30	17	13	16.2	109.1	DS	18.5	0	32	Cannon
48	578-B2	Glacial	S. Clay CL	0	9	91	28	2.69	.64	34	16	18	16.5	108.0	DS	19.0	0	28	Cannon
49	579-B1	Glacial	Silty Clay CL	0	9	91	27	2.66	.52	29	15	14	16.0	104.0	DS	17.8	0	36	Cannon
50	M-1750	Residual	S. Clay CL	-	-	-	-	2.69	-	22	14	8	12.2	119.9	DS	-	-	-	DeQueen
51	1752	Residual	S. Clay CL	-	-	-	-	2.69	-	22	13	9	11.8	121.3	DS	-	-	-	DeQueen
52	1753	Residual	S. Clay CL	-	-	-	-	2.64	-	22	13	9	11.9	121.7	DS	-	-	-	DeQueen
53	1751	Residual	S. Clay CL	0	50	50	13	2.64	.64	23	13	9	11.9	122.4	DS	12.2	.2	33.1	DeQueen
54	1754	Residual	S. Clay CL	-	-	-	-	2.69	-	28	18	10	14.0	111.8	DS	-	-	-	DeQueen
55	1756	Residual	S. Clay CL	-	-	-	-	2.68	-	26	13	13	12.5	120.0	DS	12.3	.4	32.6	DeQueen
56	9825	Residual	Silt Sandy (CL-ML)	0	56	44	15	2.67	.13	18	14	4	12.2	118.2	DS	-	-	-	DeQueen
57	9828	Residual	S. Clay CL	0	47	53	14	2.64	.71	24	14	10	14.1	116.1	DS	-	-	-	DeQueen
58	17923	Residual	S. Clay CL	0	20	80	21	2.64	.43	22	13	9	13.2	116.3	DS	15.2	0	35.9	DeQueen
59	17924	Residual	Clay, S (CL-ML)	0	47	53	20	2.72	.35	19	12	7	11.9	119.6	DS	14.0	0	35.5	DeQueen
60	17940	Residual	Clay, S (CL)	0	32	68	20	2.69	.55	23	12	11	13.0	117.0	DS	15.1	0	24.9	DeQueen
61	17948	Residual	Clay, S (CL-ML)	0	40	60	14	2.68	.50	20	13	7	13.5	117.0	DS	15.6	.1	36.3	DeQueen
62	17449	Residual	Clay, S. (CL)	0	42	58	18	2.70	.44	22	14	8	13.9	115.0	DS	16.1	.1	35.7	DeQueen
63	17	Glacial	Clay, S. (CL)	0	3	97	23	2.69	.83	39	20	19	16.8	106.5	DS	-	-	-	Saylorville
64	14	Glacial	S. Clay (CL)	0	40	60	25	2.71	.84	35	14	21	12.8	116.3	DS	-	-	-	Saylorville
65	173	Glacial	Clay CH	-	-	-	-	2.69	-	55	21	34	20.2	103.1	DS	-	-	-	Carlyle
66	33-1	Glacial	Clay CH	-	-	-	-	2.69	-	53	21	32	21.9	100.1	DS	-	-	-	Carlyle
67	33-2	Glacial	Clay CL	-	-	-	-	2.67	-	35	17	18	16.0	111.7	DS	-	-	-	Carlyle
68	34-1	Glacial	Clay CL	-	-	-	-	2.67	-	38	20	18	18.4	103.4	DS	18.0	.18	25.0	Carlyle
69	50-1	Glacial	Silty Clay	-	-	-	-	2.68	-	34	17	17	16.4	109.5	DS	22	0	33	Carlyle
70	50-2	Glacial	Clay CL	-	-	-	-	2.68	-	36	17	19	16.2	109.9	DS	-	-	-	Carlyle
71	62-1	Glacial	Clay CL	-	-	-	-	2.64	-	40	20	20	18.8	104.4	DS	18.1	.08	27	Carlyle
72	157-1	Glacial	Clay CL	-	-	-	-	2.70	-	42	18	24	17.2	107.8	DS	23.0	.02	29	Carlyle

TABLE V - SUMMARY OF SOIL TEST DATA

Observation No.		Primary Soil Division	Laboratory Classification (Unified Soil)	Mechanical Analysis Gravel	Sand	Fines	%Clay	Sp. Gr.	Act. Coeff.	LL	PL	PI	Compaction Data Opt. Water	Max.Dry Density	Shear - Data Test Type	WC	C	ϕ	Project
73	177-2	Glacial	Clay CL	-	-	-	-	2.69	-	37	20	17	16.6	109.0	DS	19.4	0	34	Carlyle
74	178-1	Glacial	Clay CH	-	-	-	-	2.71	-	64	21	43	22.6	97.3	DS	23.0	.02	29	Carlyle
75	160-1	Glacial	Clay CL	-	-	-	-	2.69	-	37	18	19	17.0	107.2	DS	19.0	.08	23.8	Carlyle
76	175-1	Glacial	Clay CL	-	-	-	-	2.68	-	40	20	20	17.2	107.9	DS	-	-	-	Carlyle
77	6	Glacial	Clay CL	-	-	-	-	2.68	-	46	19	27	17.5	103.7	DS	16	.13	27.5	Carlyle
78	22	Glacial	Clay CL	-	-	-	-	2.69	-	42	17	25	16.5	108.2	DS	16	.24	25.1	Carlyle
79	34	Glacial	Clay CL	-	-	-	-	2.67	-	38	20	18	18.4	103.4	DS	18	.18	25	Carlyle
80	53	Glacial	Clay CL	-	-	-	-	2.70	-	42	16	26	17.6	106.3	DS	21	0	25.6	Carlyle
81	66	Glacial	Clay CL	-	-	-	-	2.72	-	39	18	21	19.0	103.0	DS	24	0	30.9	Carlyle
82	7	Glacial	Clay CL	0	6	94	18	2.67	.55	30	20	10	18.5	105.2	DS	28.2	0	32.4	Rend Lake
83	1	Glacial	Clay CL	-	-	-	-	2.67	-	26	15	11	14.0	114.0	DS	18.6	0	31.5	Rend Lake
84	7	Glacial	Clay CL	-	-	-	-	2.70	-	38	16	22	15.7	110.6	DS	19.8	.06	25.3	Rend Lake
85	11	Glacial	Clay CL	-	-	-	-	2.69	-	40	20	20	21.0	99.9	DS	27.9	.01	26.1	Rend Lake
86	3	Glacial	S. Clay CL	0	19	81	23	2.69	.70	33	17	16	14.5	114.9	DS	14.4	0	34	Rend Lake
87	29	Glacial	Clay CL	0	13	87	24	2.66	.71	38	31	17	16.3	109.3	DS	19.1	.15	33	Rend Lake
88	31	Glacial	Clay CL	0	8	92	27	2.68	.56	33	18	15	18.8	105.1	DS	21.4	.11	32	Rend Lake
89	572	Glacial	Clay CL	0	4	96	35	2.66	.74	49	23	26	21.6	100.1	DS	24.1	.13	24	Rend Lake
90	573	Glacial	S. Silt (ML)	0	33	67	18	2.64	.06	17	16	1	12.8	118.4	DS	16.5	.05	34	Rend Lake
91	611	Glacial	Clay CL	0	13	87	28	2.66	.64	40	22	18	17.4	105.2	DS	23.0	.05	34	Rend Lake
92	613	Glacial	S. Clay CL	0	28	72	15	2.70	.54	26	18	8	13.5	116.1	DS	16.3	.08	35	Rend Lake
93	60	Glacial	S. Clay CL	0	22	78	20	2.69	.65	24	16	13	13.5	116.3	DS	16.4	.06	33	Rend Lake
94	42	Glacial	S. Clay CL	0	26	74	23	2.70	.87	38	18	20	16.4	115.4	DS	19.8	.10	30	Rend Lake
95	11	Residual	S. Clay CL	0	23	77	-	2.70	-	33	22	11	18.4	108.3	DS	19.5	0	29.6	Carr Fork Res.
96	17	Residual	S. Clay CL	0	38	62	15	2.70	.75	29	19	10	15.2	112.7	DS	17	0	30.7	Carr Fork Res.
97	35	Residual	S. Clay CL	0	26	74	15	2.67	.60	29	20	9	16.4	108.2	DS	18	0	31	Carr Fork Res.
98	C-A	Residual	S. Clay CL	15	24	61	-	2.74	-	30	20	10	14.2	118.0	DS	17	0	28	Carr Fork Res.
99	11765	Residual	Clay CL	7	40	53	19	2.68	1.42	38	11	27	14.0	113.2	DS	14	0	25	Proctor Res.
100	11763	Residual	Clay CL	0	7	93	30	2.68	1.00	43	18	30	18.5	101.9	DS	19	0	23.6	Proctor Res.
101	11746	Residual	Clay CH	0	22	78	17	2.72	2.30	52	13	39	18.5	105.9	DS	18	.15	16.2	Proctor Res.
102	11764	*	Clay CH	0	12	88	25	2.66	1.56	54	15	39	20.8	100.2	DS	21.5	.30	16.3	Proctor Res.
103	911	*	S. Clay CH	0	20	80	20	2.74	1.40	47	19	28	23.2	100.0	DS	-	-	-	Optima Res.
104	TP-1	*	S. Clay CL	0	49	51	-	2.65	-	37	17	26	14.8	110.0	DS	14.6	0	35	Optima Res.
105	1	Residual	Clay CH	-	-	-	-	-	-	84	41	43	19.5	99.0	DS	14.0	0	17	Clinton Res.
106	2	Residual	Clay CL	-	-	-	-	-	-	32	18	14	15.5	112.0	DS	16	0	27	Clinton Res.
107	3	Residual	Clay CH	-	-	-	-	-	-	82	42	40	20.0	99.0	DS	19	0	17	Clinton Res.
108	4	Residual	Clay CH	-	-	-	-	-	-	61	23	38	21.0	98.0	DS	21.5	0	21	Clinton Res.

* Soils of the filled valleys and Great Plains outwash mantles

TABLE V - SUMMARY OF SOIL TEST DATA

Observation No.		Primary Soil Division	Laboratory Classification (Unified Soil)	Mechanical Analysis Gravel	Sand	Fines	%Clay	Sp. Gr.	Act. Coeff.	LL	PL	PI	Compaction Data Opt. Water	Max. Dry Density	Shear - Data Type Test	WC	C	ø	Project
109	5	Residual	Clay CH	-	-	-	-	-	-	58	26	32	23.5	94.5	DS	30	0	23.3	Clinton Res.
110	7	Residual	Clay CH	-	-	-	-	-	-	58	21	37	25.0	97.0	DS	25.5	0	24	Clinton Res.
111	8	Residual	Clay CH	-	-	-	-	-	-	61	21	40	21.5	90.5	DS	24.0	0	21.5	Clinton Res.
112	10	Residual	Clay CL	-	-	-	-	-	-	40	19	21	17.5	106.5	DS	20.5	0	28	Clinton Res.
113	11	Residual	Clay CH	-	-	-	-	-	-	63	23	40	24.5	94.0	DS	28.5	0	21	Clinton Res.
114	13	Residual	Clay CL	-	-	-	-	-	-	41	23	18	18.5	101.0	DS	20.5	0	24	Clinton Res.
115	15	Residual	Clay CH	-	-	-	-	-	-	51	19	32	24.0	97.5	DS	27	0	23	Clinton Res.
116	16	Residual	Clay CH	-	-	-	-	-	-	55	20	35	20.0	99.5	DS	23.5	0	23.3	Clinton Res.
117	17	Residual	Clay CL	-	-	-	-	-	-	48	21	27	21.0	98.0	DS	21	0	26	Clinton Res.
118	18	Residual	Clay CL	-	-	-	-	-	-	43	19	24	20.0	101.0	DS	23	0	24.7	Clinton Res.
119	20	Residual	Clay CL	-	-	-	-	-	-	39	21	18	18.5	104.5	DS	21.5	0	24	Clinton Res.
120	21	Residual	Clay CL	-	-	-	-	-	-	44	17	27	20.0	103.0	DS	22.5	0	26	Clinton Res.
121	22	Residual	Clay CL	-	-	-	-	-	-	49	22	27	22.5	97.5	DS	26.5	.20	24	Clinton Res.
122	23	Residual	Clay CL	-	-	-	-	-	-	37	18	19	17.5	107.5	DS	18.5	0	30	Clinton Res.
123	24	Residual	Clay CH	-	-	-	-	-	-	42	16	26	20.0	102.0	DS	22	0	25.0	Clinton Res.
124	26	Residual	Clay CH	-	-	-	-	-	-	40	15	25	20.0	104.0	DS	22.5	0	26	Clinton Res.
125	33	Residual	Clay CL	-	-	-	-	-	-	44	16	28	21.0	101.0	DS	23.5	0	25	Clinton Res.
126	35	Residual	Clay CH	-	-	-	-	-	-	54	15	39	21.5	99.5	DS	24	0	21	Clinton Res.
127	64C	Residual	Clay CL	0	28	72	15	2.69	.60	26	13	9	12.1	118.7	DS	12.5	0	36.3	Canyon Dam
128	58C	Residual	Clay CL	0	33	67	15	2.68	.80	25	13	12	13.8	115.7	DS	13.8	0	35.3	Canyon Dam
129	71C	Residual	Clay CL	0	17	83	25	2.70	.96	35	11	24	15.6	112.6	DS	15.8	0	21	Canyon Dam
130	61C	Residual	Clay CL	0	20	80	25	2.66	.80	33	13	20	16.1	108.4	DS	16.0	0	31.2	Canyon Dam
131	66C	Residual	Clay CH	0	11	89	30	2.63	1.30	55	16	39	24.2	96.5	DS	24.2	.4	15.9	Canyon Dam
132	4443	*	Clay CL	0	12	88	35	2.67	1.06	49	14	35	16.4	109.7	DS	17.1	0	22	Bardwell
133	4434	*	Clay CH	0	19	81	18	2.67	2.34	62	20	42	23.6	95.4	DS	23.6	0	21.5	Bardwell
134	4440	*	Clay CH	0	28	72	-	2.65	-	58	16	42	19.5	102.6	DS	19.9	0	22	Bardwell
135	4441	*	Clay CH	0	24	76	24	2.66	1.74	57	14	43	15.8	109.8	DS	16.4	0	17.1	Bardwell
136	4442	*	Clay CH	0	7	93	40	2.66	1.30	72	20	52	24.4	95.6	DS	24.0	0	16.4	Bardwell
137	4444	**	Clay CL	0	27	73	23	2.67	1.09	37	12	25	14.9	113.2	DS	15.7	0	27.2	Bardwell
138	B39	**	Clay CL	0	40	60	-	2.69	-	26	13	13	12.3	118.0	DS	12.0	.24	34	AbiQuiu
139	32	**	Clay CL	0	29	71	-	2.72	-	31	15	16	15.1	113.0	DS	14.9	.06	31.2	AbiQuiu
140	B-2-3	**	Clay CL	0	30	70	-	2.74	-	29	13	16	13.7	117.2	DS	14.0	.27	28.4	AbiQuiu
141	B-1-4	**	Clay CL	0	35	65	7	2.70	2.57	32	14	18	15.4	111.9	DS	[illegible]	.20	25.7	AbiQuiu
142	1-5	**	Clay CL	2	38	60	10	2.71	1.90	33	14	19	15.0	113.4	DS	15.5	.20	29.6	AbiQuiu
143	1-6	**	Clay CL	1	29	70	23	2.71	.78	34	16	18	14.1	114.3	DS	[illegible]	.21	29.6	AbiQuiu
144	1-7	**	Clay CL	7	21	72	32	2.73	.88	48	20	28	16.0	110.7	DS	16.1	.53	27.6	AbiQuiu

* Soils of the Coastal Plains; ** Soils of the Filled Valleys and Great Plains outwash mantles

[illegible] V - SUMMARY [illegible] DATA

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Clay	[illegible]	[illegible]	[illegible]	PL	PI	Compaction Data Opt. Water	Compaction Data Max. Dry Density	[illegible]	Shear Data Wc	Shear Data c	Shear Data φ	Project
[illegible]	[illegible]		[illegible]			[illegible]	20	[illegible]	[illegible]	[illegible]	[illegible]	14	15.6	109.2		15.6	0	23.7	Navarro [illegible]
[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]		[illegible]	[illegible]	25	20	14.8	110.3		[illegible]	0	[illegible]	Navarro [illegible]
[illegible]	[illegible]	[illegible]	[illegible]				25	[illegible]	1.04	[illegible]	12	26	14.5	113.7		14.4	0	30	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	1.20	[illegible]	13	30	15.2	106.5		15.1	.4	19.8	Navarro [illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	-	[illegible]	14	31	16.2	109.8		[illegible]	0	23	Navarro [illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	-	46	17	[illegible]	18.4	104.0		[illegible]	.3	22	Navarro [illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	23.1	92.9		[illegible]	.3	17	Navarro [illegible]
[illegible]	[illegible]	[illegible]	[illegible]	0		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	45	24.0	94.0		[illegible]	0	19.3	[illegible]
[illegible]		[illegible]	[illegible]			-		2.65			[illegible]	[illegible]	15.0	110.0		[illegible]	0	[illegible]	Stockton
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]	[illegible]	[illegible]	17.5	106.0		17.0	.25	26	Stockton
[illegible]		[illegible]	[illegible]	[illegible]	15	[illegible]		[illegible]			[illegible]	[illegible]	15.0	112.0		16.0	.60	28	Stockton
[illegible]		[illegible]	[illegible]	[illegible]	17	[illegible]		[illegible]		[illegible]	[illegible]	[illegible]	21	98.5		20	.55	15	Stockton
[illegible]	4	Residual	[illegible]	-	4	[illegible]				[illegible]	22	35	21	100.5		24	0	20	Stockton
[illegible]	[illegible]	Residual	[illegible]	[illegible]	-		[illegible]		-	[illegible]	20	32	21	106.0		-	-	-	Stockton
[illegible]		Residual	[illegible]	[illegible]			-		-	[illegible]	18	[illegible]	13.3	97.0	[illegible]	-	-	-	Stockton
[illegible]	[illegible]	Residual	[illegible]	0		[illegible]	-	[illegible]	-	[illegible]	[illegible]	[illegible]	38.0	76.5	[illegible]	41	0	20	Stockton
[illegible]	9	Residual	[illegible]	0	[illegible]	[illegible]	-	[illegible]		35	[illegible]	[illegible]	16.9	109.0	[illegible]	17	0	29	Stockton
[illegible]	10	[illegible]	[illegible]	0		[illegible]	-	[illegible]	-	46			17.5	107.0	[illegible]	18	0	26	Stockton
[illegible]	12	[illegible]	[illegible]	[illegible]	[illegible]	63	[illegible]	[illegible]	-	62			22	98.5	[illegible]	26	0	19	Stockton
[illegible]	[illegible]	Residual	[illegible]	0	8	92	-	[illegible]	-	40	[illegible]	[illegible]	28	107.5	DS	21	0	28	Stockton
165	14	Residual	Clay CL	0	2	98	-	2.66		40	22	[illegible]	18	105.0	DS	20	0	27	Stockton
166	15	Residual	Clay CH	0	15	85	-	2.77	-	77	29	48	31	85.0	DS	35	0	17	Stockton
167	16	Residual	Clay CL	0	20	80	-	2.64	-	30	20	10	16	110.5	DS	19	0	30	Stockton
168	A-20	Residual	Clay CL	0	9	91	-	2.68	-	42	18	24	17.5	104.1	DS	16.7	.40	27.4	Table Rock Dam
169	A-30	Residual	S. Clay CL	0	35	65	-	2.69	-	23.6	13.1	10.5	12.2	120.4	DS	11.8	.48	28.4	Table Rock Dam
170	36-1	Residual	S. Clay CL	0	37	63	-	2.68	-	23.9	13.2	10.7	12.4	120.1	DS	12.3	.35	34.2	Table Rock Dam
171	36-2	Residual	S. Clay CL	0	42	58	14	2.68	.85	24.9	13.0	11.9	12.7	119.2	DS	12.2	.27	34.6	Table Rock Dam
172	B-5	Residual	Clay CL	0	7	93	21	2.65	.48	39.6	19.5	10.1	18.2	104.2	DS	23.4	.41	21.8	Table Rock Dam
173	10	Residual	S. Clay CL	0	22	78	-	2.67	-	26.2	15.1	11.1	12.5	118.1	DS	13.1	.50	33.1	Table Rock Dam
174	20	Residual	S. Clay CL	0	24	76	-	2.67	-	24.6	14.3	10.3	14.0	116.0	DS	-	-	-	Table Rock Dam
175	13	Residual	S. Clay CL	0	37	63	-	2.68	-	23.2	12.0	10.3	12.0	121.0	DS	-	-	-	Table Rock Dam
176	38	Residual	S. Clay CL	0	26	74	-	2.68	-	39.3	15.5	23.8	16.0	111.1	DS	14.2	.30	33.4	Table Rock Dam
177	17	Residual	S. Clay CL	0	24	76	23	2.67	.80	32.2	13.8	18.4	14.6	115.8	DS	14.1	.60	27.5	Table Rock Dam
178	32	Residual	S. Clay CL	0	5	95	-	2.65	-	35.3	16.6	18.7	15.6	112.1	DS	15.1	.65	27.3	Table Rock Dam
179	41	Residual	S. Clay CL	0	45	55	-	2.66	-	22.1	14.3	7.8	12.0	117.9	DS	12.0	.32	32.6	Table Rock Dam
180	62	Residual	S. Clay CL	0	40	60	-	2.67	-	23.3	13.6	9.7	11.9	120.5	DS	-	-	-	Table Rock Dam

* Soils of the Coastal Plain

TABLE V - SUMMARY OF SOIL TEST DATA

Observation No.		Primary Soil Division	Laboratory Classification (Unified Soil)	Mechanical Analysis				Sp. Gr.	Act. Coeff.	LL	PL	PI	Compaction Data		Shear - Data				Project
				Gravel	Sand	Fines	%Clay						Opt. Water	Max. Dry Density	Test Type	WC	C	∅	
181	36	Residual	S. Clay CL	0	15	85	-	2.68	-	28.4	14.9	13.5	13.5	116.7	DS	13.2	.60	33.5	Table Rock Dam
182	1	Residual	Clay CH	-	-	-	-	-	-	51	22	29	21	102.0	DS	23	0	21	Melvern
183	2	Residual	Clay CL	-	-	-	-	-	-	37	14	23	16.3	106.0	DS	19	0	29.5	Melvern
184	3	Residual	Clay CL	-	-	-	-	-	-	41	19	22	17.5	108.0	DS	21	0	27.5	Melvern
185	4	Residual	Clay CL	-	-	-	-	-	-	49	19	30	16.5	104.0	DS	15	0	26.5	Melvern
186	5	Residual	Clay CL	-	-	-	-	-	-	40	20	20	18.0	104.0	DS	22	0	26.5	Melvern
187	6	Residual	Clay CH	-	-	-	-	-	-	63	24	39	24.0	96.5	DS	29	0	18.5	Melvern
188	7	Residual	Clay CL	-	-	-	-	-	-	36	11	15	16.0	107.0	DS	19	0	31.5	Melvern
189	8	Residual	Clay CL	-	-	-	-	-	-	44	20	24	21.0	102.4	DS	23	0	25.6	Melvern
190	9	Residual	Clay CL	-	-	-	-	-	-	49	19	30	22.0	100.5	DS	24	0	27.5	Melvern
191	10	Residual	Clay CH	-	-	-	-	-	-	42	22	20	17.5	104.0	DS	21	0	27.5	Melvern
192	11	Residual	Clay CL	-	-	-	-	-	-	55	24	31	21.0	99.5	DS	26	0	19.3	Melvern
193	12	Residual	Clay CL	-	-	-	-	-	-	42	20	22	19.0	103.0	DS	23	0	23.8	Melvern
194	13	Residual	Clay CL	-	-	-	-	-	-	44	21	23	16.0	106.5	DS	20	0	23.4	Melvern
195	14	Residual	Clay CH	-	-	-	-	-	-	65	24	41	25	94.5	DS	27	0	21	Melvern
196	15	Residual	Clay CL	-	-	-	-	-	-	37	20	17	17	105.5	DS	15	0	27.5	Melvern
197	16	Residual	Clay CL	-	-	-	-	-	-	36	19	17	17.7	108.0	DS	21	0	31.5	Melvern
198	17	Residual	Clay CH	-	-	-	-	-	-	59	23	36	28.0	98.5	DS	25	0	22.5	Melvern
199	18	Residual	Clay CH	-	-	-	-	-	-	47	23	24	22.0	100.5	DS	25	0	26.5	Melvern
200	20	Residual	Clay CL	-	-	-	-	-	-	39	20	19	17.2	108.0	DS	19	0	31.0	Melvern
201	21	Residual	Clay CL	-	-	-	-	-	-	40	27	19	20.3	105.0	DS	23	0	25.5	Melvern
202	22	Residual	Clay CL	-	-	-	-	-	-	46	20	26	19	103.5	DS	22	0	27.5	Melvern
203	23	Residual	Clay CL	-	-	-	-	-	-	46	20	26	20	101.0	DS	23	0	28.5	Melvern
204	24	Residual	Clay CL	-	-	-	-	-	-	49	32	17	20.5	102.5	DS	23	0	26.5	Melvern
205	25	Residual	Clay CL	-	-	-	-	-	-	55	25	30	22	100.5	DS	25	0	25.5	Melvern
206	26	Residual	Clay CL	-	-	-	-	-	-	59	24	35	20.1	105.0	DS	-	0	31	Melvern
207	1	Residual	ML	0	43	57	-	2.57	-	41	26	15	18.2	106.0	DS	13	.11	24	Hartwell Res.
208	3	Residual	ML	0	49	51	-	2.64	-	42	28	14	18.2	106.0	DS	19	.10	35	Hartwell Res.
209	5	Residual	ML	0	46	54	-	2.66	-	37	15	22	20.0	104.1	DS	21	.49	17	Hartwell Res.
210	C-8	Residual	CH	0	45	55	-	2.65	-	52	27	25	19.5	103.1	DS	22	.13	38.5	Hartwell Res.
211	C-9	Residual	ML	0	62	38	-	2.67	-	41	32	9	16.4	108.3	DS	16	0	37.5	Hartwell Res.
212	C-15	Residual	CL	0	48	52	-	2.68	-	38	26	12	18.4	104.3	DS	20	0	35	Hartwell Res.
213	C-16	Residual	ML	0	55	45	-	2.70	-	34	29	5	16.4	105.8	DS	16	0	41.5	Hartwell Res.
214	C-21	Residual	ML	0	60	40	-	2.72	-	26	27	5	16.2	111.8	DS	16	0	35.5	Hartwell Res.
215	BB	Residual	Clay CL	0	25	75	-	-	-	47	20	27	19.0	106.0	DS	16	0	35.5	Bruce-Eddie Dam
216	BA	Residual	Clay CL	0	31	69	-	-	-	35	18	17	15.6	113.2	DS	-	-	-	Bruce-Eddie Dam

TABLE V - SUMMARY OF SOIL TEST DATA

Observation No.		Primary Soil Division	Laboratory Classification (Unified Soil)	Mechanical Analysis				Sp. Gr.	Act. Coeff.	LL	PL	PI	Compaction Data		Shear - Data				Project
				Gravel	Sand	Fines	%Clay						Opt. Water	Max.Dry Density	Type Test	WC	C	ø	
217	A-26	Residual	Silt ML	0	22	78	-	-	-	32	24	8	16.7	111.7	DS	-	-	-	Bruce-Eddie Dam
218	AP-19	Residual	Silt (CL-ML)	0	35	65	-	-	-	26	21	5	14.0	117.6	DS	-	-	-	Bruce-Eddie Dam
219	AP-5	Residual	Clay CL	0	45	55	-	-	-	38	22	16	15.0	117.2	DS	-	-	-	Bruce-Eddie Dam
220	AP-1	Residual	Clay CL	0	38	62	-	-	-	37	23	14	15.0	114.3	DS	-	-	-	Bruce-Eddie Dam
221	AP-76	Residual	Clay CL	0	22	78	-	-	-	36	19	17	14.6	114.0	DS	-	-	-	Bruce-Eddie Dam
222	AP-70	Residual	Clay CL	0	8	92	-	2.73	-	39	18	21	19.3	107.0	DS	22	0	30	Bruce-Eddie Dam
223	73	Residual	Clay CL	0	7	93	25	2.71	.88	41	19	22	20.3	103.0	DS	18	0	27	Bruce-Eddie Dam
224	B-63	*	Clay CH	0	3	97	-	2.60	-	58	27	31	27.8	89.5	DS	-	-	-	Okatibbec Creek
225	7-1	*	Clay CL	0	14	86	-	2.61	-	46	26	20	22.0	100.5	DS	-	-	-	Okatibbec Creek
226	7-2	*	Clay CH	0	8	92	-	2.67	-	56	26	30	24.0	96.4	DS	-	-	-	Okatibbec Creek
227	12-1	*	Clay CL	0	44	56	-	2.62	-	37	20	17	17.0	108.0	DS	-	-	-	Okatibbec Creek
228	27-1	*	Clay CH	0	22	78	-	2.58	-	45	22	23	21.2	101.0	DS	-	-	-	Okatibbec Creek
229	7-3	*	Clay CH	0	5	95	-	2.62	-	62	26	36	24.8	94.9	DS	25.5	0	22	Okatibbec Creek
230	C-2	*	Clay CL	0	20	80	-	2.64	-	48	22	26	19.8	104.2	DS	20.3	0	24.5	Okatibbec Creek
231	32820	Residual	Clay CH	0	17	83	34	2.59	1.03	59	24	35	27.5	90.8	DS	27.2	0	22	Martis Creek
232	32319	Residual	Clay CL	0	42	58	18	2.66	1.28	44	21	23	22.3	101.0	DS	21.5	0	30	Martis Creek
233	39076	Residual	Clay CL	0	32	68	-	2.65	-	52	26	26	25.5	94.8	DS	23.4	0	32	Martis Creek
234	103	**	Clay CL	-	-	-	-	-	-	29	7	22	15.2	114.0	DS	-	.03	25	Coyote Valley
235	105	**	Clay CL	-	-	-	-	-	-	28	16	12	14.6	116.0	DS	-	0	29	Coyote Valley
236	242	**	Clay CL	0	23	77	-	2.69	-	43	18	25	17.9	109.0	DS	-	.12	19	Coyote Valley
238	264	**	Clay CL	0	2	98	-	2.73	-	48	25	23	19.2	107.0	DS	-	0	23	Coyote Valley
239	89	**	Clay CL	0	4	96	-	2.72	-	42	17	25	16.7	110.6	DS	12.5	0	23	Coyote Valley
240	C-A	Residual	Clay CL	0	4	96	25	2.67	.86	43.5	22	21.5	18.0	106.8	DS	-	-	-	Monroe Reservoir
241	C-B	Residual	Clay CH	0	5	95	48	2.74	.76	61.1	24.7	36.4	26.5	95.5	DS	31.3	.18	18.1	Monroe Reservoir
242	C-C	Residual	Clay CH	0	17	83	42	2.74	1.06	68.7	24.0	44.7	22.7	100.0	DS	27.2	.17	23	Monroe Reservoir
243	C-D	Residual	Clay CL	0	11	89	32	2.76	.71	40.4	17.6	22.8	16.4	110.5	DS	21.4	.09	26	Monroe Reservoir
244	C-A	Glacial	Clay CL	15	22	63	22	2.75	.57	32.1	19.5	12.6	12.8	122.6	DS	18.1	0	23.2	Union City
245	C-C	Glacial	S. Clay CL	23	24	53	13	2.74	.82	30.1	19.4	10.7	12.6	123.0	DS	17.6	0	28.4	Union City
246	C-X	Glacial	S, Silty Clay CL	6	13	81	8	2.69	1.00	30.3	22.1	8.2	16.6	108.0	DS	17.9	0	33.5	Union City
247	C-Y	Glacial	S Cr Clay CL	26	16	58	-	2.73	-	29.2	19.1	10.1	10.8	125.5	DS	13.9	0	31.3	Union City
248	C-Z	Glacial	Gr S, Clay CL	13	24	63	-	2.75	-	28	17.3	10.7	11.4	124.8	DS	-	-	-	Union City
249	C-A	Glacial	S. Clay CL	3	22	75	16	2.66	1.25	38.3	18.2	20.1	15.5	112.0	DS	18.7	.25	18.4	Green River
250	C-B	Glacial	Gr. S. Clay	13	32	55	14	2.66	1.24	35.4	18.0	17.4	13.9	114.3	DS	18.9	.15	23.5	Green River
251	C-F	Glacial	Silty Clay	0	10	90	20	2.69	.38	30.5	22.9	7.6	17.6	108.0	DS	20.6	.05	31.4	Green River
252	C-G	Glacial	Gr. S. Clay	13	24	63	25	2.71	.69	41.7	24.5	17.2	17.5	105.8	DS	25	0	31.4	Green River

* Soils of the Coastal Plains; ** Soils of the Filled Valleys and Great Plains outwash mantles

TABLE V - SUMMARY OF SOIL TEST DATA

Observation No.		Primary Soil Division	Laboratory Classification (Unified Soil)	Mechanical Analysis Gravel	Sand	Fines	%Clay	Sp. Gr.	Act. Coeff.	LL	PL	PI	Compaction Data Opt. Water	Max. Dry Density	Shear - Data Type Test	WC	C	Ø	Project
253	C-1	Glacial	S. Clay CL	0	15	85	15	2.67	.70	32.6	22.1	10.5	20.0	104.6	DS	22.5	0	29.5	Green River
254	C-2	Glacial	Clay CL	0	15	85	24	2.69	.51	33.1	20.9	12.2	18.6	108.2	DS	21.6	0	30.6	Green River
255	C-3	Glacial	Clay CL	13	12	25	18	2.69	.75	36	22.5	13.5	18.6	107.8	DS	20.7	0	31.0	Green River
256	A	Residual	S. Clay CL	0	31	69	24	2.70	.55	30.9	12.7	13.1	16.4	111.4	DS	17.6	0	32	Cpue Run
257	C	Residual	S. Clay CL	0	30	70	15	2.68	.77	28	16.5	11.5	15.7	112.3	DS	17	0	31	Cpue Run
258	D	Residual	S. Clay CL	0	8	92	35	2.73	.59	41.7	21	20.7	17	109.8	DS	19.2	0	23	Cpue Run
259	64487	Loessial	S. Silt ML	2	46	52	10	2.68	.69	30.3	23.4	6.9	17.3	106.2	DS	-	-	-	Eau Galleau
260	634176	Loessial	S. Clay CL	0	36	64	25	2.73	.57	29.7	15.5	14.2	15.5	114.2	DS	15.5	0	18.8	Eau Galleau
261	634175	Loessial	S. H Clay (CL-ML)	0	10	90	13	2.72	.45	26	20.2	5.8	15.5	113.2	DS	15.6	0	31.8	Eau Galleau
262	64489	Loessial	S. H Clay (CL-ML)	0	5	95	15	2.70	.43	26.8	20.3	6.5	16.0	111.5	DS	15.9	0	36.2	Eau Galleau
263	64400	Loessial	C. Clay CL	3	28	69	28	2.73	.37	37.2	16.9	10.3	16.0	112.8	DS	16.1	0	26.3	Eau Galleau
264	10634	Residual	Clay CL	1	17	82	-	2.71	-	28	13	15	13.8	114.5	DS	14	.1	29.8	Waco
265	10637	Residual	Clay CL	7	25	68	-	2.69	-	29	13	16	12.7	118.3	DS	13	.1	28.5	Waco
266	10626	Residual	Clay CL	4	32	64	-	2.62	-	30	12	18	16.0	110.2	DS	16	0	25.7	Waco
267	10636	Residual	Clay CL	2	23	75	-	2.64	-	37	15	22	15.2	110.2	DS	15	.1	23.8	Waco
268	10630	Residual	Clay CL	0	14	86	-	2.67	-	43	13	30	16.4	109.5	DS	17	0	23	Waco
269	10630	Residual	Clay CL	0	7	93	-	2.64	-	46	15	31	18.7	102.7	DS	19	.1	26.7	Waco
270	10631	Residual	Clay CL	0	7	93	-	2.64	-	46	15	31	22.4	96.6	DS	22	.2	27	Waco
271	10632	Residual	Clay CL	0	14	86	-	2.67	-	43	13	30	19.3	101.3	DS	20	0	23	Waco
272	A-11	**	Clay CL	0	26	74	18	2.69	.78	25	11	14	13.0	116.2	DS	11.2	.2	33.4	Hugo
273	A-18	**	Clay CH	0	6	94	59	2.71	.78	66	20	46	22.2	98.4	DS	20.4	.3	22.3	Hugo
274	C-12	**	Clay CL	0	32	68	34	2.69	.77	39	13	26	15.8	110.0	DS	-	-	-	Hugo
275	D-14	**	Clay CL	12	26	62	28	2.72	1.00	42	14	28	16.4	110.1	DS	-	-	-	Hugo
276	B-3	Glacial	Clay CL	9	35	56	-	2.74	-	30	15	15	14.3	110.0	-	-	-	-	Westville
277	U-9	Residual	Clay CH	0	0	100	-	2.69	-	54	28	26	*22	100.0	DS	30	.61	12	Tuttle Creek
278	U-10	Residual	Clay CL	0	2	98	-	2.69	-	40	23	17	*18	108.0	DS	37	.23	15	Tuttle Creek
279	U-10	Residual	Clay CH	0	0	100	-	2.72	-	63	24	39	*23	102.0	DS	30	.27	10	Tuttle Creek
280	TP19	Residual	Clay CL	0	2	98	-	2.65	-	36	14	22	*14	118.0	DS	12	0	30	Tuttle Creek
281	C-53	Residual	Clay CL	0	0	100	-	2.68	-	37	15	22	21	100.0	DS	16	.40	11	Tuttle Creek
282	C-33	Residual	Clay CL	0	0	100	-	2.68	-	37	15	22	21	100.0	DS	20	.40	13	Tuttle Creek
283	D-177	Residual	Clay CL	0	4	96	-	2.69	-	41	23	18	20	102.8	DS	26	.40	23.3	Tuttle Creek
284	D-177	Residual	Clay CL	0	4	96	-	2.69	-	41	23	18	20	102.8	DS	25	.20	19.3	Tuttle Creek
285	D-347	Residual	Clay CL	0	5	95	-	2.68	-	33	18	15	19	101.0	DS	24	.12	22	Tuttle Creek
286	D-199	Residual	Clay CL	0	10	90	-	2.66	-	32	23	9	19	103.5	DS	18.8	.18	28	Tuttle Creek
287	D-199	Residual	Clay CL	0	10	90	-	2.66	-	32	23	9	19	103.5	DS	24	.07	28	Tuttle Creek
288	A	Glacial	S. Clay CL	0	37	63	12	2.71	.99	26.6	14.7	11.9	12.6	121.0	DS	14.9	0	30	Buck Creek

** Soils of the Coastal Plains

TABLE V - SUMMARY OF SOIL TEST DATA

Observation No.		Primary Soil Division	Laboratory Classification (Unified Soil)	Mechanical Analysis Gravel	Sand	Fines	%Clay	Sp. Gr.	Act. Coeff.	LL	PL	PI	Compaction Data Opt. Water	Max. Dry Density	Shear - Data Type Test	WC	C	Ø	Project
289	B	Glacial	S Silt Clay (CL-ML)	9	43	48	9	2.74	.79	19.7	12.6	7.1	8.9	130.1	DS	11.0	0	31	Buck Creek
290	C	Glacial	S Silt Clay (CL-ML)	2	38	60	7	2.66	1.00	24.1	17.1	7.0	14.7	113.3	DS	17.2	0	32	Buck Creek
291	644	Loessial	Clay CL	-	-	-	-	2.70	-	35.3	20.8	14.5	19.3	104.9	DS	14.9	0	32	La Farce
292	644	Loessial	Clay CL	0	2	98	18	2.74	.62	30.6	19.5	11.1	16.5	110.7	DS	16.6	0	35	La Farce
293	Y-36	Loessial	Clay CL	0	0	100	-	2.69	-	38.9	20.4	18.5	20.9	104.3	DS	20.9	0	30	La Farce
294	Y-37	Loessial	Clay CL	0	0	100	5	2.70	2.04	30.5	20.3	10.2	16.5	109.5	DS	16.6	0	32	La Farce
295	Y-38	Loessial	Clay CL	0	0	100	18	2.73	.64	32	20.5	11.5	17.6	108.8	DS	17.6	0	30	La Farce
296	Y-304	Loessial	Clay CL	0	2	98	24	2.73	1.01	43.2	19.1	24.1	21.4	102.6	DS	21.4	0	29.6	La Farce
297	Y-305	Loessial	Clay CL	0	2	98	10	2.73	1.07	24.9	19.2	10.7	17.2	109.0	DS	17.3	0	33.6	La Farce
298	LB-3	Residual	Clay CL	3	32	65	13	2.69	.69	28	19	9	12.2	117.4	DS	12.5	0	31	Roystown
299	P	Residual	Clay CL	-	-	-	-	2.70	-	28	19	9	14.4	116.2	DS	14.7	0	31	Roystown
300	366	Residual	Clay CL	0	39	61	17	2.69	.65	30	19	11	12.6	117.4	DS	17.2	0	35	Roystown
301	3	Residual	Silt ML	0	49	51	-	2.64	-	42	28	14	18.2	106.0	DS	19.0	.10	35	Hartwell Dam
302	5	Residual	Silt ML	0	46	54	-	2.66	-	37	15	22	22.0	104.1	DS	21	.44	17	Hartwell Dam
303	6	Residual	Silt ML	0	46	54	-	2.68	-	44	32	17	16.8	105.3	DS	18	0	41	Hartwell Dam
304	7	Residual	Silt ML	0	45	55	-	2.65	-	49	27	22	19.5	103.1	DS	22	.13	38.5	Hartwell Dam
305	8	Residual	Silt ML	0	62	38	-	2.67	-	41	32	9	16.4	109.3	DS	16	0	37.5	Hartwell Dam
306	9	Residual	Silt ML	0	48	52	-	2.68	-	38	26	12	18.4	104.3	DS	20	0	35	Hartwell Dam
307	10	Residual	Silt ML	-	-	-	-	2.70	-	34	24	5	16.4	105.8	DS	16	0	41.5	Hartwell Dam
308	96	Residual	Clay CL	0	25	75	28	2.75	.72	41	21	20	17.6	113.0	DS	17.7	0	24.5	New Hope
309	30	Residual	Clay CL	-	-	-	-	2.69	-	47	25	22	20.8	102.6	DS	23.3	0	28.5	New Hope
310	21	Residual	Clay CH	0	16	84	40	2.69	1.22	80	31	49	25.4	96.8	DS	32.8	0	23	New Hope
311	15	Residual	Clay CH	0	28	72	25	2.79	.44	31	20	11	14.4	115.0	DS	14.9	0	29.3	New Hope
312	10	Residual	Clay CH	-	-	-	-	2.69	-	75	30	45	26.8	90.1	DS	-	-	-	New Hope
313	10[2]	Residual	Clay CH	0	21	79	44	2.69	1.02	75	30	45	26.0	91.8	DS	21.3	0	17.5	New Hope
314	15	Residual	Clay CL	-	-	-	-	2.79	-	31	20	11	14.4	115.0	DS	-	0	29.5	Carters
315	90	Residual	Clay CL	-	-	-	-	2.75	-	41	21	20	17.6	113.0	DS	17.7	0	24.5	Carters
316	91	Residual	Clay CL	-	-	-	-	2.68	-	42	25	22	20.8	102.5	DS	21.4	0	30.5	Carters
317	92	Residual	Clay CL	-	-	-	-	2.73	-	75	30	45	26.8	90.1	DS	27.3	0	16	Carters

SUMMARY OF BUREAU OF PUBLIC ROADS DATA AND DEVIATIONS OF ACTUAL VALUES FROM PREDICTED VALUES

TABLE VI

	Location Sampled	Soil Name	BPR Sample No.	LL	PL	PI	Actual Opt.	Actual Max. d.	Predicted Max. density	Actual-Predicted Max. Deviation
1.	Alabama	Allen loam	27799	20	16	4	11	122	117.3	-4.7
2.	Alabama	Atkins S. loam	27803	26	19	7	14	112	114.5	+2.5
3.	Alabama	Capshaw silt loam	27804	21	17	4	12	116	116.8	+0.8
4.	Alabama	Capshaw silt loam	27805	25	15	10	12	121	115.3	-5.7
5.	Alabama	Capshaw silt loam	27806	32	20	12	15	116	111.5	-4.5
6.	Alabama	Capshaw silt loam	27807	32	19	13	15	115	111.7	-3.3
7.	Alabama	Capshaw silt loam	27808	37	20	17	16	113	109.3	-2.4
8.	Alabama	Capshaw silt loam	27809	64	30	34	24	99	95.9	-3.3
9.	Alabama	Colbert silt loam	27810	23	18	5	13	117	115.7	-1.3
10.	Alabama	Colbert silt loam	27812	55	28	27	21	102	100.0	-2.0
11.	Alabama	Clarksville silt loam	27813	27	23	4	17	113	113.3	+0.3
12.	Alabama	Clarksville silt loam	27814	24	20	4	14	113	115.2	+2.2
13.	Alabama	Crossville silt loam	27816	36	25	11	19	106	109.0	+3.0
14.	Alabama	Crossville silt loam	27817	37	26	11	18	105	108.5	+3.5
15.	Alabama	Apison silt loam	27821	21	17	4	13	112	116.7	+4.7
16.	Alabama	Apison silt loam	27823	35	24	11	18	108	109.8	+1.8

	Location Sampled	Soil Name	BPR Sample No.	LL	PL	PI	Actual Opt.	Actual Max. d.	Predicted Max. density	Actual-Predicted Max. Deviation
17.	Alabama	Greendale silt loam	27830	29	22	7	13	114	112.5	-1.5
18.	Alabama	Johnsburg loam	27838	25	18	7	13	117	115.0	-2.0
19.	Alabama	Johnsburg loam	27839	43	24	19	19	108	107.8	-0.2
20.	Arizona	Showlow loam	31799	26	19	7	14	112	114.5	+2.5
21.	Arizona	Showlow loam	31801	38	19	19	12	116	109.0	-7.0
22.	Arizona	Showlow loam	31802	30	19	11	15	110	112.5	+2.5
23.	Arizona	Springerville clay	31807	65	32	33	29	90	95.0	+5.0
24.	Arkansas	Boswell sandy loam	33162	62	29	33	27	95	96.8	+1.8
25.	Arkansas	Boswell sandy loam	33163	47	23	24	21	105	104.2	-0.8
26.	Arkansas	Boswell sandy loam	33165	70	33	37	25	94	92.6	-1.4
27.	Arkansas	Boswell sandy loam	33169	71	36	35	27	91	91.8	+0.8
28.	Connecticut	Walpole sandy loam	31686	31	25	6	17	108	111.3	+2.7
29.	Connecticut	Walpole sandy loam	31687	24	20	4	13	117	115.4	-1.6
30.	Connecticut	Cheshire sandy loam	32092	20	17	3	11	122	117.3	-4.7
31.	Connecticut	Cheshire sandy loam	32097	24	21	3	15	111	115.2	+4.2
32.	Florida	Manatee sandy loam	28103	28	15	13	13	118	114.1	-3.9
33.	Florida	Manatee sandy loam	28104	26	12	14	11	124	115.2	-8.8
34.	Florida	Manatee sandy loam	28122	20	16	4	12	119	117.2	-1.8
35.	Florida	Manatee sandy loam	28125	20	18	2	14	114	117.0	+3.0

	Location Sampled	Soil Name	BPR Sample No.	LL	PL	PI	Actual Opt.	Actual Max. d.	Predicted Max. density	Actual-Predicted Max. Deviation
36.	Illinois	Fayette silt loam	32971	28	22	6	15	108	113.1	+5.1
37.	Illinois	Fayette silt loam	32972	44	23	21	19	106	105.7	-0.3
38.	Illinois	Fayette silt loam	32975	46	23	23	19	107	104.8	-2.2
39.	Illinois	Fayette silt loam	32977	27	21	6	15	111	113.9	+2.9
40.	Illinois	Fayette silt loam	32980	36	26	10	18	103	108.8	+5.8
41.	Illinois	Herrick silt loam	32982	39	22	17	17	110	108.1	-1.9
42.	Illinois	Herrick silt loam	32984	69	32	37	24	96	93.2	-2.8
43.	Illinois	Hickory loam	32986	27	21	6	14	110	113.8	+3.8
44.	Illinois	Hickory loam	32987	40	19	21	17	110	108.0	-2.0
45.	Kentucky	Tilsit silt loam	31445	29	23	6	17	105	112.5	+7.5
46.	Kentucky	Tilsit silt loam	31447	46	23	23	19	102	104.4	+2.4
47.	Kentucky	Tilsit silt loam	31448	38	20	18	17	108	108.5	+0.5
48.	Kentucky	Russell silt loam	31451	39	24	15	18	106	107.9	+1.9
49.	Kentucky	Pembroke silt loam	31453	25	22	3	15	105	114.6	+9.6
50.	Kentucky	Pembroke silt loam	31455	60	24	36	22	100	98.0	-2.0
51.	Kentucky	Bewleyville silt loam	31457	46	25	21	19	105	104.5	-0.5
52.	Kentucky	Bewleyville silt loam	31458	37	23	14	17	109	110.3	+1.3
53.	Kentucky	Bewleyville silt loam	31459	43	20	23	21	103	106.5	+3.5

	Location Sampled	Soil Name	BPR Sample No.	LL	PL	PI	Actual Opt.	Actual Max. d.	Predicted Max. density	Actual-Predicted Max. Deviation
54.	Minnesota	Hayden silt loam	31213	32	16	16	14	114	112.0	-2.0
55.	Minnesota	Hayden loam	31215	22	19	3	12	114	116.1	+2.1
56.	Minnesota	Hayden loam	31216	34	17	17	14	113	111.2	-1.8
57.	Minnesota	Webster silty clay loam	31219	36	20	16	18	104	109.8	+5.8
58.	Minnesota	Webster silty clay loam	31223	58	20	38	22	99	99.2	+0.2
59.	Minnesota	Lester silt loam	31228	43	21	22	19	104	106.3	+2.3
60.	Minnesota	Lester silt loam	31230	38	23	15	19	104	108.6	+4.6
61.	Minnesota	Lester silt loam	31231	35	20	15	16	109	110.1	+1.1
62.	Nebraska	Altvan loam	32353	30	22	6	15	109	112.2	+3.2
63.	Nebraska	Rosebud loam	32359	29	19	10	16	109	113.1	+4.1
64.	Nebraska	Rosebud loam	32363	33	21	12	19	105	110.8	+5.8
65.	Nebraska	Rosebud loam	32366	40	21	19	19	104	107.4	+3.4
66.	Nebraska	Rosebud loam	32369	52	24	20	23	96	100.9	+4.9
67.	Nebraska	Rosebud loam	32373	21	16	5	12	119	116.9	-2.1
68.	N. Carolina	Georgeville silt loam	31332	71	37	34	29	90	91.8	+1.8
69.	N. Carolina	Georgeville silt loam	31333	70	37	33	29	90	92.1	+2.1
70.	N. Carolina	Orange silt loam	31334	24	20	4	14	112	115.3	+3.3

	Location Sampled	Soil Name	BPR Sample No.	LL	PL	PI	Actual Opt.	Actual Max. d.	Predicted Max. density	Actual-Predicted Max. Deviation
71.	N. Carolina	Orange silt loam	31335	46	18	28	17	111	105.5	-5.5
72.	N. Carolina	Iredell loam	31338	66	24	38	21	102	97.2	-4.8
73.	N. Carolina	Davidson clay loam	31341	70	38	32	27	93	92.0	-1.0
74.	N. Carolina	Davidson clay loam	31342	84	44	40	31	87	84.9	-2.1
75.	N. Carolina	Lloyd loam	31343	47	35	12	24	91	102.8	+11.8
76.	N. Carolina	Lloyd loam	31344	80	44	36	29	90	86.7	-3.3
77.	Oregon	Gemstony loam	32462	39	22	17	18	109	108.2	-0.8
78.	Texas	Lufkin sandy loam	29075	64	25	39	20	102	96.4	-5.6
79.	Texas	Lufkin sandy loam	29077	53	22	31	20	101	102.0	+2.8
80.	Texas	Lufkin sandy loam	29082	61	26	35	23	98	97.5	+0.2
81.	Texas	Abilene clay loam	32127	46	21	25	21	104	105.2	+1.2
82.	Texas	Abilene clay loam	32129	32	16	16	13	118	112.0	-6.0
83.	Texas	Abilene clay loam	32130	28	17	11	18	108	113.9	+5.9
84.	Texas	Abilene clay loam	32133	43	16	27	15	113	106.8	-6.2
85.	Texas	Abilene clay loam	32134	30	18	12	17	107	112.7	+5.7
86.	Texas	Abilene clay loam	32137	34	17	17	17	111	110.9	-0.1
87.	Texas	Covington silty loam	31544	43	31	17	23	95	105.8	+10.8
88.	Texas	Covington silty loam	31546	80	34	46	32	87	88.0	+1.0

	Location Sampled	Soil Name	BPR Sample No.	LL	PL	PI	Actual Opt.	Actual Max. d.	Predicted Max. density	Actual-Predicted Max. Deviation
89.	Texas	Covington silty loam	31548	24	20	4	14	117	115.2	-1.8
90.	Texas	Covington silty loam	31549	27	19	8	14	117	113.8	-3.2
91.	Ohio	Paulding clay	31540	77	32	45	26	95	90.7	-4.3
92.	Ohio	Paulding clay	31542	63	28	35	23	101	96.4	-4.6
93.	Alabama	Litz silty loam	27840	32	24	8	17	107	111.0	+5.0
94.	Alabama	Linker silty loam	27844	41	28	13	19	106	106.4	+0.4
95.	Alabama	Melvin silt loam	27846	24	18	6	12	106	115.3	-0.7
96.	Alabama	Minvale silt loam	27847	27	20	7	13	112	113.9	+1.9
97.	Alabama	Minvale silt loam	27848	29	18	11	13	117	113.2	-3.8
98.	Alabama	Talbot silty clay loam	27852	26	16	10	13	116	114.8	-1.2
99.	Alabama	Muskingum sandy loam	27851	22	16	6	12	119	116.3	-2.7
100.	Alabama	Muskingum sandy loam	27850	24	19	5	14	110	115.3	+5.3

SUMMARY OF BUREAU OF PUBLIC ROADS DATA AND
DEVIATIONS OF ACTUAL VALUES FROM PREDICTED VALUES

TABLE VII

	Location Sampled	Soil Name	BPR Sample No.	LL	PL	PI	Actual Opt.	Actual Max. d.	Predicted Opt.	Opt. Deviation Actual-Predicted
1.	Alabama	Allen loam	27799	20	16	4	11	122	12.5	+1.5
2.	Alabama	Atkins S. loam	27803	26	19	7	14	112	14.2	+0.2
3.	Alabama	Capshaw silt loam	27804	21	17	4	12	116	12.8	+0.8
4.	Alabama	Capshaw silt loam	27805	25	15	10	12	121	13.6	+1.5
5.	Alabama	Capshaw silt loam	27806	32	20	12	15	116	15.8	+0.8
6.	Alabama	Capshaw silt loam	27807	32	19	13	15	115	15.8	+0.8
7.	Alabama	Capshaw silt loam	27808	37	20	17	16	113	17.1	+1.1
8.	Alabama	Capshaw silt loam	27809	64	30	34	24	99	25.3	+1.3
9.	Alabama	Colbert silt loam	27810	23	18	5	13	117	13.5	+0.5
10.	Alabama	Colbert silt loam	27812	55	28	27	21	102	22.2	+1.2
11.	Alabama	Clarksville silt loam	27813	27	23	4	17	113	14.9	-2.9
12.	Alabama	Clarksville silt loam	27814	24	20	4	14	113	18.8	-0.2
13.	Alabama	Crossville silt loam	27816	36	25	11	19	106	17.3	-1.7
14.	Alabama	Crossville silt loam	27817	37	26	11	18	105	17.8	-0.2
15.	Alabama	Apison silt loam	27821	21	17	4	13	112	13.1	+0.1
16.	Alabama	Apison silt loam	27823	35	24	11	18	108	17.0	+1.0

SUMMARY OF BUREAU OF PUBLIC ROADS DATA AND
DEVIATIONS OF ACTUAL VALUES FROM PREDICTED VALUES

TABLE VII

	Location Sampled	Soil Name	BPR Sample No.	LL	PL	PI	Actual Opt.	Actual Max. d.	Predicted Opt.	Opt. Deviation Actual-Predicted
1.	Alabama	Allen loam	27799	20	16	4	11	122	12.5	+1.5
2.	Alabama	Atkins S. loam	27803	26	19	7	14	112	14.2	+0.2
3.	Alabama	Capshaw silt loam	27804	21	17	4	12	116	12.8	+0.8
4.	Alabama	Capshaw silt loam	27805	25	15	10	12	121	13.6	+1.5
5.	Alabama	Capshaw silt loam	27806	32	20	12	15	116	15.8	+0.8
6.	Alabama	Capshaw silt loam	27807	32	19	13	15	115	15.8	+0.8
7.	Alabama	Capshaw silt loam	27808	37	20	17	16	113	17.1	+1.1
8.	Alabama	Capshaw silt loam	27809	64	30	34	24	99	25.3	+1.3
9.	Alabama	Colbert silt loam	27810	23	18	5	13	117	13.5	+0.5
10.	Alabama	Colbert silt loam	27812	55	28	27	21	102	22.2	+1.2
11.	Alabama	Clarksville silt loam	27813	27	23	4	17	113	14.9	-2.9
12.	Alabama	Clarksville silt loam	27814	24	20	4	14	113	18.8	-0.2
13.	Alabama	Crossville silt loam	27816	36	25	11	19	106	17.3	-1.7
14.	Alabama	Crossville silt loam	27817	37	26	11	18	105	17.8	-0.2
15.	Alabama	Apison silt loam	27821	21	17	4	13	112	13.1	+0.1
16.	Alabama	Apison silt loam	27823	35	24	11	18	108	17.0	+1.0

	Location Sampled	Soil Name	BPR Sample No.	LL	PL	PI	Actual Opt.	Actual Max. d.	Predicted Opt.	Opt. Deviation Actual-Predicted
17.	Alabama	Greendale silt loam	27830	29	22	7	13	114	15.3	+2.3
18.	Alabama	Johnsburg loam	27838	25	18	7	13	117	13.9	+0.9
19.	Alabama	Johnsburg loam	27839	43	24	19	19	108	18.8	+0.2
20.	Arizona	Showlow loam	31799	26	19	7	14	112	14.3	+0.3
21.	Arizona	Showlow loam	31801	38	19	19	12	116	17.2	+5.2
22.	Arizona	Showlow loam	31802	30	19	11	15	110	15.2	+0.2
23.	Arizona	Springerville clay	31807	65	32	33	29	90	24.8	-4.2
24.	Arkansas	Boswell sandy loam	33162	62	29	33	27	95	23.9	-3.1
25.	Arkansas	Boswell sandy loam	33163	47	23	24	21	105	20.0	-1.0
26.	Arkansas	Boswell sandy loam	33165	70	33	37	25	94	26.1	+1.1
27.	Arkansas	Boswell sandy loam	33169	71	36	35	27	91	26.7	-0.3
28.	Connecticut	Walpole sandy loam	31686	31	25	6	17	108	16.1	-0.9
29.	Connecticut	Walpole sandy loam	31687	24	20	4	13	117	13.9	+0.9
30.	Connecticut	Cheshire sandy loam	32092	20	17	3	11	122	12.7	+1.7
31.	Connecticut	Cheshire sandy loam	32097	24	21	3	15	111	13.9	-1.1
32.	Florida	Manatee sandy loam	28103	28	15	13	13	118	14.3	+1.3
33.	Florida	Manatee sandy loam	28104	26	12	14	11	124	13.6	+2.6
34.	Florida	Manatee sandy loam	28122	20	16	4	12	119	12.5	+0.5
35.	Florida	Manatee sandy loam	28125	20	18	2	14	114	12.8	-1.2

	Location Sampled	Soil Name	BPR Sample No.	LL	PL	PI	Actual Opt.	Actual Max. d.	Predicted Opt.	Opt. Deviation Actual-Predicted
36.	Illinois	Fayette silt loam	32971	28	22	6	15	108	15.1	+0.1
37.	Illinois	Fayette silt loam	32972	44	23	21	19	106	19.0	0.0
38.	Illinois	Fayette silt loam	32975	46	23	23	19	107	19.7	+0.7
39.	Illinois	Fayette silt loam	32977	27	21	6	15	111	14.8	-0.2
40.	Illinois	Fayette silt loam	32980	36	26	10	18	103	17.4	-0.6
41.	Illinois	Herrick silt loam	32982	39	22	17	17	110	17.7	+0.7
42.	Illinois	Herrick silt loam	32984	69	32	37	24	96	25.8	+1.8
43.	Illinois	Hickory loam	32986	27	21	6	14	110	14.8	+0.8
44.	Illinois	Hickory loam	32987	40	19	21	17	110	17.8	+0.8
45.	Kentucky	Tilsit silt loam	31445	29	23	6	17	105	15.4	-1.6
46.	Kentucky	Tilsit silt loam	31447	46	23	23	19	102	19.4	+0.4
47.	Kentucky	Tilsit silt loam	31448	38	20	18	17	108	17.5	+0.5
48.	Kentucky	Russell silt loam	31451	39	24	15	18	106	18.0	0.0
49.	Kentucky	Pembroke silt loam	31453	25	22	3	15	105	14.2	-0.8
50.	Kentucky	Pembroke silt loam	31455	60	24	36	22	100	23.9	+1.9
51.	Kentucky	Bewleyville silt loam	31457	46	25	21	19	105	19.7	+0.7
52.	Kentucky	Bewleyville silt loam	31458	37	23	14	17	109	17.3	+0.3
53.	Kentucky	Bewleyville silt loam	31459	43	20	23	21	103	18.4	-2.6

	Location Sampled	Soil Name	BPR Sample No.	LL	PL	PI	Actual Opt.	Actual Max. d.	Predicted Opt.	Opt. Deviation Actual-Predicted
54.	Minnesota	Hayden silt loam	31213	32	16	16	14	114	15.5	+1.5
55.	Minnesota	Hayden loam	31215	22	19	3	12	114	13.2	+1.2
56.	Minnesota	Hayden loam	31216	34	17	17	14	113	16.0	+2.0
57.	Minnesota	Webster silty clay loam	31219	36	20	16	18	104	16.8	-1.2
58.	Minnesota	Webster silty clay loam	31223	58	20	38	22	99	22.0	0.0
59.	Minnesota	Lester silt loam	31228	43	21	22	19	104	18.7	-0.3
60.	Minnesota	Lester silt loam	31230	38	23	15	19	104	17.6	-1.4
61.	Minnesota	Lester silt loam	31231	35	20	15	16	109	16.6	+0.6
62.	Nebraska	Altvan loam	32353	30	22	6	15	109	15.6	+0.6
63.	Nebraska	Rosebud loam	32359	29	19	10	16	109	15.0	-1.0
64.	Nebraska	Rosebud loam	32363	33	21	12	19	105	16.2	-2.8
65.	Nebraska	Rosebud loam	32366	40	21	19	19	104	17.9	-1.1
66.	Nebraska	Rosebud loam	32369	52	24	20	23	96	21.8	-1.2
67.	Nebraska	Rosebud loam	32373	21	16	5	12	119	12.8	+0.8
68.	N. Carolina	Georgeville silt loam	31332	71	37	34	29	90	26.8	-2.2
69.	N. Carolina	Georgeville silt loam	31333	70	37	33	29	90	26.7	-2.3
70.	N. Carolina	Orange silt loam	31334	24	20	4	14	112	13.8	-0.2

	Location Sampled	Soil Name	BPR Sample No.	LL	PL	PI	Actual Opt.	Actual Max. d.	Predicted Opt.	Opt. Deviation Actual-Predicted
71.	N. Carolina	Orange silt loam	31335	46	18	28	17	111	18.8	+1.8
72.	N. Carolina	Iredell loam	31338	66	24	38	21	102	23.3	+2.3
73.	N. Carolina	Davidson clay loam	31341	70	38	32	27	93	26.8	-0.2
74.	N. Carolina	Davidson clay loam	31342	84	44	40	31	87	30.7	-0.3
75.	N. Carolina	Lloyd loam	31343	47	35	12	24	91	21.0	-3.0
76.	N. Carolina	Lloyd loam	31344	80	44	36	29	90	29.7	+0.7
77.	Oregon	Gemstony loam	32462	39	22	17	18	109	17.8	+0.2
78.	Texas	Lufkin sandy loam	29075	64	25	39	20	102	23.9	+3.9
79.	Texas	Lufkin sandy loam	29077	53	22	31	20	101	21.0	+1.0
80.	Texas	Lufkin sandy loam	29082	61	26	35	23	98	23.5	+0.5
81.	Texas	Abilene clay loam	32127	46	21	25	21	104	19.2	-1.8
82.	Texas	Abilene clay loam	32129	32	16	16	13	118	15.4	+2.4
83.	Texas	Abilene clay loam	32130	28	17	11	18	108	14.5	-3.5
84.	Texas	Abilene clay loam	32133	43	16	27	15	113	18.0	+3.0
85.	Texas	Abilene clay loam	32134	30	18	12	17	107	15.2	-1.8
86.	Texas	Abilene clay loam	32137	34	17	17	17	111	16.0	-1.0
87.	Texas	Covington silty loam	31544	43	31	17	23	95	19.0	-4.0
88.	Texas	Covington silty loam	31546	80	34	46	32	87	28.6	-3.4

	Location Sampled	Soil Name	BPR Sample No.	LL	PL	PI	Actual Opt.	Actual Max. d.	Predicted Opt.	Opt. Deviation Actual-Predicted
89.	Texas	Covington silty loam	31548	24	20	4	14	117	13.8	-0.2
90.	Texas	Covington silty loam	31549	27	19	8	14	117	14.5	+0.5
91.	Ohio	Paulding clay	31540	77	32	45	26	95	27.8	+1.8
92.	Ohio	Paulding clay	31542	63	28	35	23	101	24.0	+1.0
93.	Alabama	Litz silty loam	27840	32	24	8	17	107	16.2	-0.8
94.	Alabama	Linker silty loam	27844	41	28	13	19	106	18.8	-0.2
95.	Alabama	Melvin silt loam	27846	24	18	6	12	106	13.7	+1.7
96.	Alabama	Minvale silt loam	27847	27	20	7	13	112	14.7	+1.7
97.	Alabama	Minvale silt loam	27848	29	18	11	13	117	14.9	+1.9
98.	Alabama	Talbot silty clay loam	27852	26	16	10	13	116	13.9	+0.9
99.	Alabama	Muskingum sandy loam	27851	22	16	6	12	119	13.1	+1.1
100.	Alabama	Muskingum sandy loam	27850	24	19	5	14	110	13.7	-0.3

Table VIII
Summary of Regression Analysis (Arithmetic Equations)

Analysis No.	Developed Equation	Std. Error of Estimate	Multiple Correlation Coefficient	Scope of Consider-ation
1	C = - .010 + .005 PI - .003 Opt. + .001 PL	.06	.59	Glacial
2	(C = .875 + .003 PI - .002 (W.C.) + .016 (A.C.) - .012 (Opt.) - .005 Max. d. - .001% F)	.12	.31	All soils
3	C = .18 - .008 (W.C.) + .002 (L.L.)	.14	.19	All soils
4	C = .21 - .006 (P.L.) - .001 (W.C.)	.14	.23	All soils
5	C = .22 - .01 (W.C.) + .003 (PI)	.14	.26	" "
6	C = .13 - .015 (W.C.) + .013 (Opt.)	.14	.23	" "
7	C = .73 - .011 (W.C.) - .004 Max. d.	.14	.20	" "
8	(C = .19 - .013 (PL) + .008 (L.L.) - .012 (WC) + .01 (Opt.) - .006 (P.I.))	.13	.30	" "
9	(C = - .95 - .002 (PL) - .02 (W.C.) + .03 (Opt) + .009 (Max. d.) + .017 (L.L.) = .015 (P.I.))	.41	.15	Residual
10	(Max. d. = 112.3 - .36 (L.L.) - .45 (%F) - .35 (PL) - .36 (%S) - .03 (P.I.))	3.66	.90	All soils
11	(Max. d. = 76.6 - .47 (LL) - .33 (%F) + 30.2 (S.G.) - .25 (%S))	3.68	.898	" "
12	(Max. d. = 78.6 - .94 (PL) - .32 (%F) + 28.2 (S.G.) - .13 (%S))	5.49	.75	" "

Table VIII

Summary of Regression Analysis (Arithmetic Equations)

Analysis No.	Developed Equation	Std. Error of Estimate	Multiple Correlation Coefficient	Scope of Consider-ation
13	(Max. d. = 87.3 - .47 (PI) - .39 (%F) - .29 (%S) + 25.08 (S.G.))	5.29	.77	All soils
14	Max. d. = 127.4 - .49 (L.L.)	4.17	.85	" "
15	Max. d. = 128.8 - .53 (L.L.) + .07 (PI) - .53 (P.L.)	4.15	.86	" "
16	Max. d. = 125.5 - .95 (P.L.)	6.54	.58	" "
17	Max. d. = 119.0 - .54 (P.I.)	5.04	.78	" "
18	Max. d. = 116.0 - 8.06 (A.C.)	7.46	.42	" "
19	Max. d. = 122.3 - .55 (%C)	6.16	-.66	" "
20	(Max. d. = 174.3 - .37 (L.L.) - .48 (%F) - .42 (PL) - .29 (%S))	2.87	.94	St. Louis District
21	(Max. d. = 159.1 - .44 (L.L.) - .33 (%F) - .19 (PL) - .24 (%S) + .01 (P.I.))	3.91	.90	Residual
22	(Max. d. = 178.2 - .52 (%F) - .86 (LL) - .33 (%S) + .57 (PI))	3.43	.86	Glacial
23	(Max. d. = 123.9 - .77 (LI) + .17 (%S) + .38 (PI) + .03 (%F) + .29 (A.C.))	2.73	.98	Meramec Park

Table VIII
Summary of Regression Analysis (Arithmetic Equations)

Analysis No.	Developed Equation	Std. Error of Estimate	Multiple Correlation Coefficient	Scope of Consider-ation
24	(Max. d. = 140.93 - 1.0 (LL) + .71 (PI) - .12 (%F) - .05 (%S)	3.30	.92	Coastal Plains
25	(Max. d. = 130.3 - .39 (LL) - .35 (PL) - .02 (PI) + .04 (A.C)	4.02	.88	All soils
26	(Ø = 34.04 - .58 (PI) + .33 (Opt.) - .26 (PL) + .12 (L.L.))	3.07	.77	Glacial
27	(Ø = - 6.76 - .16 (PI) + .41 (PL) + .31 (Max. d.) + .09 (W.C.) - .08 (LL) - .07 (Opt.))	4.17	.74	Residual
28	(Ø = 26.8 - .31 (PI) - 1.86 (AC) + .25 (Opt.) + .07 (Max. d.) - .06 (WC) - .01 (%F))	3.69	.79	All soils
29	Ø = 37.5 - .28 (LL) + .06 (WC)	4.69	.62	" "
30	Ø = 36.3 - .70 (WC) + .25 (PL)	5.18	.49	" "
31	Ø = 34.5 - .37 (PI) + .04 (WC)	4.20	.71	" "
32	Ø = 19.4 + .43 (Max. d.) + .05 (WC)	4.99	.54	" "
33	(Ø = 25.1 + .03 (PI) + .57 (PL) - .36 (LL) + .07 (Max. d.) - 07 (Opt.) + .01 (WC))	3.87	.75	" "
34	Ø = 41.3 - 1.0 (Opt.) + .18 (WC)	4.98	.54	" "

Table VIII
Summary of Regression Analysis (Arithmetic Equations)

Analysis No.	Developed Equation	Std. Error of Estimate	Multiple Correlation Coefficient	Scope of Consideration
35	(Opt = 4.51 + .2 (LL) + .25 (PL) - .23 (AC) + .03 (PI))	1.94	.91	All soils
36	(Opt = 8.80 + .22 (LL) + .15 (%F) + .18 (PL) + .11 (%S) + .01 (PI))	1.75	.92	" "
37	(Opt = 8.60 + .26 (PI) + .16 (%F) + .12 (%S) + .16 (%F))	2.94	.76	" "
38	(Opt = - 2.92 + .27 (LL) + .14 (%F) + .10 (%S) - 1.03 (S.G.))	1.89	.91	" "
39	(Opt = - 22.8 + .54 (PL) + .22 (%F) + .13 (%S) + 3.69 (SG)	3.05	.73	" "
40	Opt = 6.55 + .39 (LL) - .16 (PI) - .07 (PL)	1.99	.88	" "
41	Opt = 7.12 + .26 (LL)	2.02	.87	" "
42	Opt = 71.09 - .5 (max. d.)	1.28	.95	" "
43	Opt = 8.27 + .5 (PL)	3.39	.59	" "
44	Opt = 11.45 + .29 (PI)	2.50	.80	" "
45	Opt = 13.3 + 4.25 (A.C.)	3.90	.42	" "
46	Opt = 9.67 + .31 (%C)	3.42	.66	" "

Table VIII
Summary of Regression Analysis (Arithmetic Equations)

Analysis	Developed Equation	Std. Error of Estimate	Multiple Correlation Coefficient	Scope of Consider-ation
47	(Opt = - 3.55 + .33 (LL) + .12 (%F) - .12 (PI) + .04 (%S))	1.94	.91	St. Louis
48	(Opt = - 7.87 + .23 (LL) + .15 (%F) + .12 (%S) + .08 (PL) + .04 (PI))	1.91	.93	Residual
49	(Opt = - 12.08 + .19 (%F) + .39 (PL) + .12 (%S) + .11 (LL))	1.34	.88	Glacial
50	(Opt = -5.77 + .49 (LL) + .03 (%S) + 4.34 (A.C) - .28 (PI) + .07 (%F))	1.71	.98	Meramec Park
51	Opt = 6.50 + .45 (PL) + .13 (LL) - .07 (%S)	1.30	.95	Coastal
52	Opt = 6.23 + .34 (LL) - .11 (PI)	2	.88	All Soils
53	Max. d. = 128.4 - .58 (LL) + .13 (PI)	4.15	.86	" "

Table VIII
Summary of Regression Analysis (Logarithmic Equations)

Analysis No.	Developed Equations	Std. Error of Estimate	Multiple Correlation Coefficient	Scope of Consider-ation
14-A	log Max. d. = 2.35 - .20 log (LL)	4.03	.86	All soils
15-A	(log Max. d. = 2.40 - .28 log (LL) + .05 log (PI) + .01 log (P.L))	3.98	.87	" "
16-A	log Max. d. = 2.26 - .18 log (LL)	6.32	.59	" "
17-A	log Max. d. = 2.15 - .10 log (P.I.)	5.23	.72	" "
18-A	log Max. d. = 2.03 - .07 log (A.C)	7.39	.43	" "
19-A	log Max. d. = 2.17 - .57 log (%C)	6.32	.57	" "
20-A	(log Max. d. = 2.63 - .34 log (LL) + .08 log (P.I) - .10 log (%F) + .02 log (PL) + 00 (%S))	2.94	.91	St. Louis Dist.
22-A	(log Max. d. = 2.67 - .22 log (%F) - .11 log (LL) + .02 log (PI) - .01 log (%S) - .03 log (P.L))	3.61	.83	Glacial
23-A	(log Max. d. = 2.80 - .58 log (LL) + .23 log (A.C) - .08 log (%F) - .01 (%S))	2.77	.98	Meramec Park.
24-A	(log Max. d. = 2.30 + .03 log (%S) - .35 log (LL) + .16 log (PI) + .01 log (%F))	3.36	.91	Coastal Plains
25-A	(log Max. d. = 2.40 - .24 log (LL) + .03 log (PI) - .03 log (PL) + .01 log (A.C))	3.98	.87	All soils

Table VIII

Summary of Regression Analysis (Logarithmic Equations)

Analysis No.	Developed Equations	Std. Error of Estimate	Multiple Correlation Coefficient	Scope of Consideration
26-A	(log Ø =1.88 - .92 log (LL) + .55 log (PL) + .14 log (PI) + .45 log (Opt))	3.31	.73	Glacial
27-A	(log Ø = 1.01 - .16 log (PI) - .48 log (Opt) + .22 log (PL) + .16 log (W.C) + .40 log (Max. d.) - .06 log (LL))	4.22	.74	Residual
28-A	(log Ø = .59 - 21 log (PI) + .46 log (Max. d.) + .15 log (%F) - 10 log (O.P.T) + .01 log (M.C) + .01 log (W.C))	3.88	.76	All soils
29-A	log Ø = 2.08 - .45 log (LL) + .06 log (W.C)	4.78	.60	" "
30-A	log Ø = 1.84 - .50 log (WC) + .17 log (PL)	5.37	.44	" "
31-A	log Ø = 1.80 - .25 log (PI) - .04 log (W.C)	4.48	.66	" "
32-A	log Ø = - 2.84 + 2.02 log (Max. d.) + .13 log (W.C)			
33-A	(log Ø = 1.61 + .04 log (PI) + .17 log (Max. d.) + .43 log (P.L) - .22 log (L.L) - .13 log (Opt) + .02 log (W.C))	3.92	.74	All soils
34-A	log Ø = 2.12 - .76 log (OPT) + .19 log (W.C)	5.13	.53	" "
35-A	(log OPT = .08 + .56log (LL) + .19 log (PL) - .05 log (A.C) - .02 log (P.I))	2.06	.89	" "
40-A	log OPT = .17 + .71 log (LL) - .09 (PI) + .04 (PL)	2.01	.88	" "

Table VIII

Summary of Regression Analysis (Logarithmic Equations)

Analysis No.	Developed Equation	Std. Error of Estimate	Multiple Correlation Coefficient	Scope of Consider-ation
41-A	$\log OPT = .29 + .60 \log (LL)$	2.07	.87	All soils
42-A	$\log OPT = 6.89 - 2.77 \log (Max.\ d.)$	1.21	.96	" "
43-A	$\log OPT = .55 + .54 \log (P.L)$	3.17	.61	" "
44-A	$\log OPT = .88 + .28 \log (PI)$	2.79	.73	" "
45-A	$\log OPT = 1.24 + .9 \log (A.C)$	3.85	.43	" "
46-A	$\log OPT = .80 + .32 \log (\%C)$	3.69	.59	" "
47-A	$(\log OPT = -.45 + .78 \log (L.L) + .33 \log (\%F) - .15 \log (P.I) + .01 \log (P.L) + 00 \%S)$	1.84	.93	St. Louis
49-A	$(\log OPT = - 1.17 + .76 \log (\%F) + .27 \log (PL) + .37 \log (L.L) + .08 \log (\%S) - .05 \log (P.I))$	1.41	.87	Glacial
50-A	$(\log OPT = - 1.37 + 1.34 \log (LL) - .41 \log (P.I) + .49 \log (\%F) + .06 \log (\%S) - .03 \log (A.C))$	1.59	.99	Meramec
51-A	$(\log OPT = .17 + .42 \log (PL) + .27 \log (LL) - .05 \log (\%S) + .11 \log (\%F))$	1.23	.96	Coastal Plains.

Chart I - Rating Chart of Graphical Plots
(Glacial Soils)

Correlation	LINEAR RATING-ARITHMETIC			LINEAR RATING-LOGIO		
	Signif-icant	Slightly Signif-icant	Insig-nificant	Signif-icant	Slightly Signif-icant	Insig-nificant
Maximum Dry Density						
LL	X					
PL		X				
PI		X				
%S	X					
%F	X					
%C		X				
A.C.		X				
Opt. W.C.	X					
S.G.			X			
Optimum Water Content						
LL	X					
PL	X					
PI		X				
%S	X					
%F	X					
%C		X				
A.C.		X				
S.G.			X			
Angle of Internal Friction						
Max. d.		X				
Opt. W.C.		X				
LL	X					
PL			X			
PI	X					
%F		X				
%S		X				
Sample W.C.		X				
A.C.		X				
Cohesion						
Max. d.		X				
Opt. W.C.		X				
LL	X					
PL			X			
PI	X					
%F		X				
%S		X				
Sample W.C.			X			
A.C.			X			
S.G.			X			

Chart II - Rating Chart of Graphical Plots
(Residual Soils)

Correlation	LINEAR RATING-ARITHMETIC			LINEAR RATING-LOGIO		
	Signif-icant	Slightly Signif-icant	Insig-nificant	Signif-icant	Slightly Signif-icant	Insig-nificant
Maximum Dry Density						
LL	X					
PL	X					
PI	X					
%S		X				
%F		X				
%C	X					
A.C.		X				
Opt. W.C.	X					
S.G.			X			
Optimum Water Content						
LL	X					
PL	X					
PI	X					
%S		X				
%F		X				
%C	X					
A.C.		X				
S.G.			X			
Angle of Internal Friction						
LL	X					
PL			X			
PI	X					
%S		X				
%F		X				
%C		X				
A.C.		X				
Sample W.C.	X					
Opt. W.C.	X					
Max. d.						
S.G.			X			
Cohesion						
LL			X			
PL			X			
PI			X			
%S			X			
%F			X			
%C			X			
A.C.			X			
Opt. W.C.			X			
S.G.			X			

Chart III - Rating Chart of Graphical Plots
All Soils

Correlation	LINEAR RATING-ARITHMETIC			LINEAR RATING-LOGIO		
	Signif-icant	Slightly Signif-icant	Insig-nificant	Signif-icant	Slightly Signif-icant	Insig-nificant
Maximum Dry Density						
LL	X					
PL	X					
PI	X					
%S		X				
%F		X				
%C	X					
A.C.		X				
Opt. W.C.	X					
S.G.			X			
Optimum Moisture Content						
LL	X			X		
PL	X			X		
PI	X			X		
%S		X				
%F		X				
%C	X					
A.C.		X				
S.G.			X			
Angle of Internal Friction						
Max. d.	X					
LL	X			X		
Opt. W.C.	X			X		
%F			X			
PL			X			
PI	X			X		
%S			X			
Sample W.C.		X				
A.C.		X				
Cohesion						
Max. d.			X			
LL			X			
Opt. W.C.			X			
%F			X			
PL			X			
PI			X			
%S			X			
Sample W.C.			X			
AC			X			

LEGEND OF ABBREVIATIONS AND SYMBOLS

LL	=	Liquid Limit
PL	=	Plastic Limit
PI	=	Plasticity Index
Opt.	=	Optimum Moisture Content
Max.d.	=	Maximum Dry Density
c	=	Cohesion (T.S.F.)
∅	=	Angle of Internal Friction Degrees
W.C.	=	Average Water Content of Direct Shear Specimens
A.C.	=	Activity Coefficient
% F	=	Percent Fines
% S	=	Percent Sand
% C	=	Percent Clay
S.G.	=	Specific Gravity

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VIII. Vita

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